

GNSS Orbit RPR model Considerations

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15/04/2019

Introduction



- Investigate the systematic effects between the AC orbits
 - Potential IIF issue
- Try to reduce the draconic terms in our products
 - Must be coming from orbit modelling errors
- Define “minimal requirements” for the orbit model for repro3
 - And routine solutions



Current Orbit RPR Models



- JPL GSPM model (JPL, EMR)
- ECOM approach, 5 parameters with “pulses” (GFZ, NGS?)
- ECOM approach, 9 parameters with constraints and/or long arc (MIT, SIO)
- ECOM2 approach, 7 parameters (ECOM 5 + DC2 & DS2) with “pulses” (COD)
- IGS Box-wing model (ESA)
- GRGS approach, box-wing (?), Y-bias and 4 CPRs in X&Z direction (or D&B?)



2018 Investigation; focus IIF

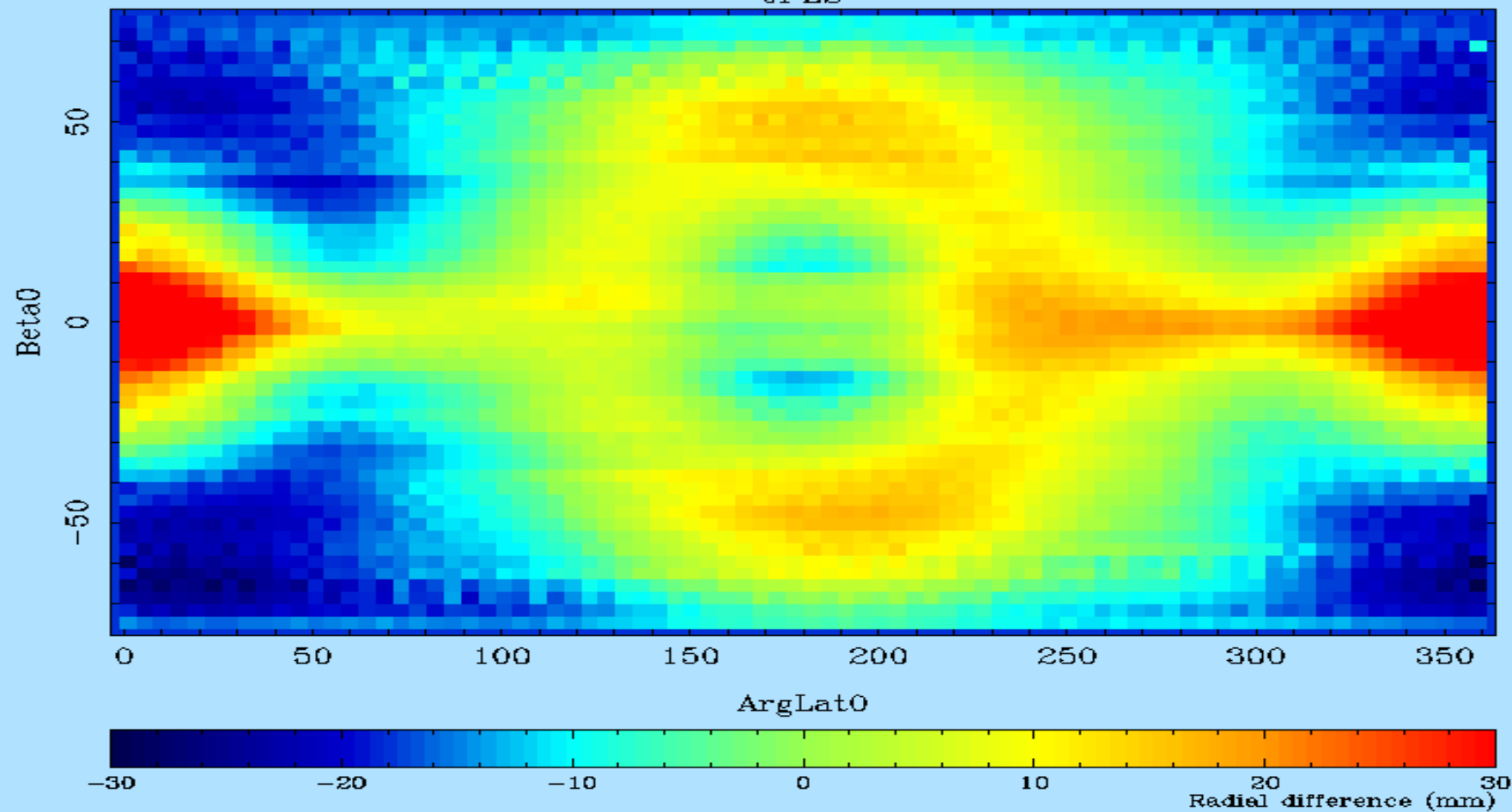


- GPS weeks 1970 to 2024 (8-Oct-2017 to 27-Oct-2018)
- All IGS AC Final Orbits
- Compared in radial-, along-, and cross-track
 - Against IGS Final and against JPL
- Compared separately per GPS block type and GLONASS
- Results were distributed to orbit working group and AC e-mail list



SP3 Orbit and Clock Differences

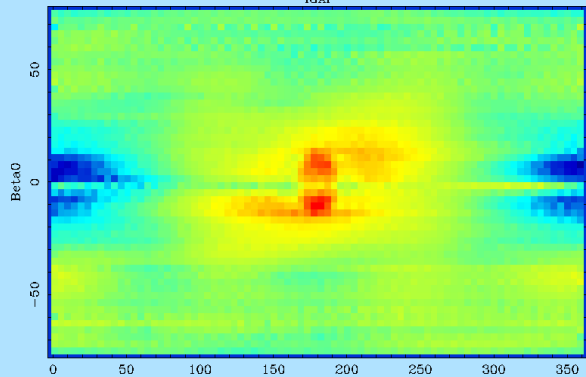
JPES



IIF Radial Differences (AC vs IGS)

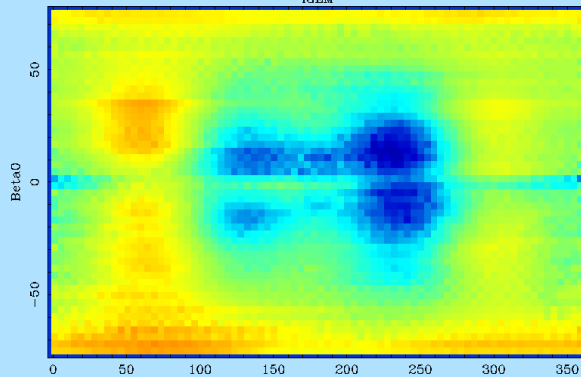
SP3 Orbit and Clock Differences

IGAI



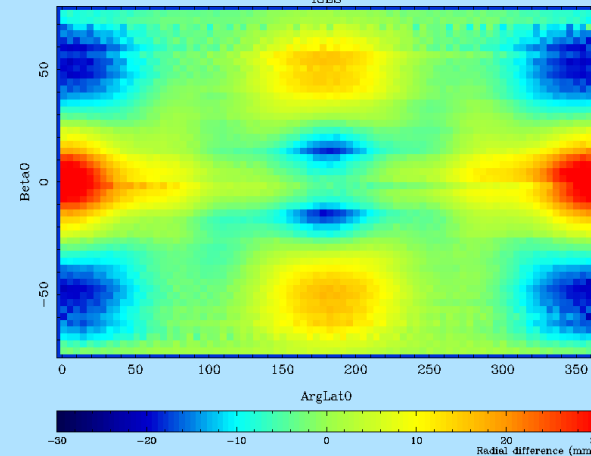
SP3 Orbit and Clock Differences

IGEM



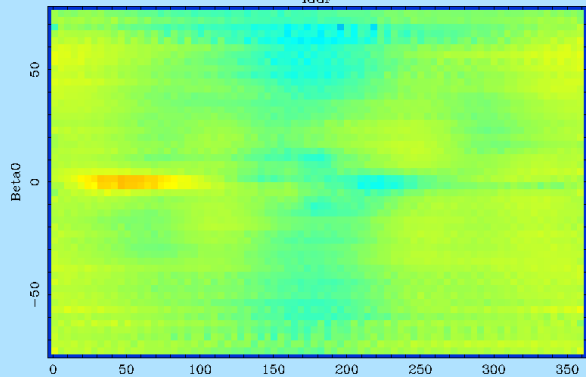
SP3 Orbit and Clock Differences

IGES



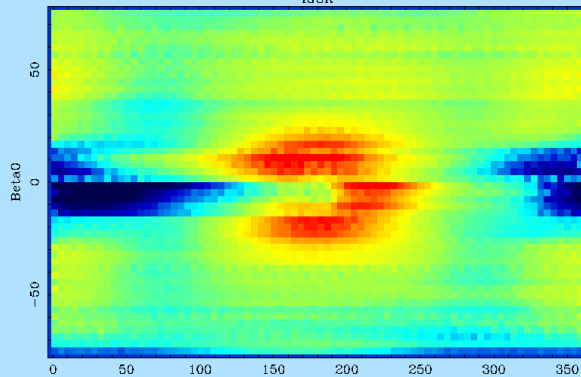
SP3 Orbit and Clock Differences

IGGF



SP3 Orbit and Clock Differences

IGGR



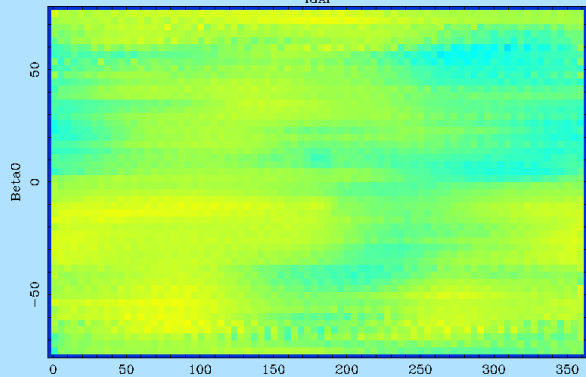
EMR JPL similar

GFZ NGS MIT SIO similar

IIF Cross-track Differences (AC vs IGS)

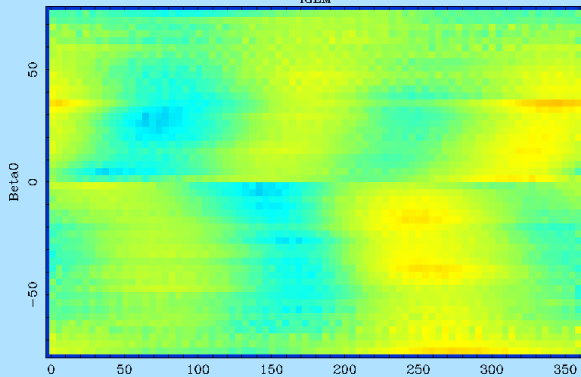
SP3 Orbit and Clock Differences

IGAI



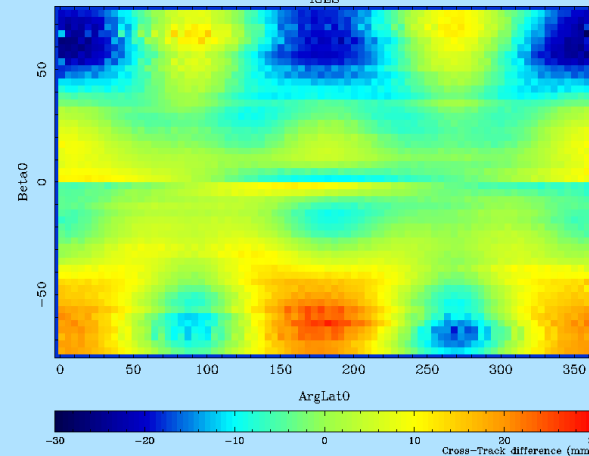
SP3 Orbit and Clock Differences

IGEM



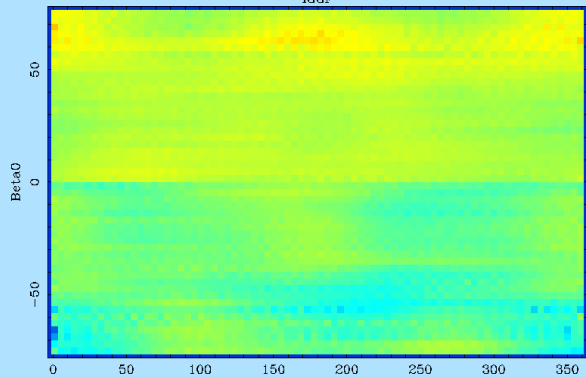
SP3 Orbit and Clock Differences

IGES



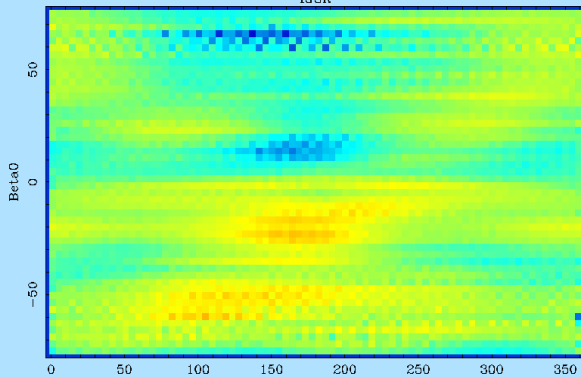
SP3 Orbit and Clock Differences

IGGF



SP3 Orbit and Clock Differences

IGGR



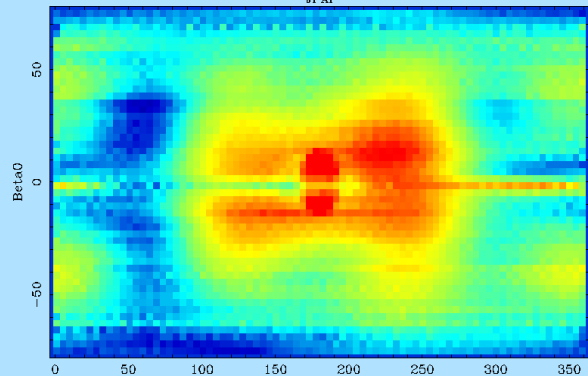
EMR JPL similar

GFZ NGS MIT SIO similar

IIF Radial Differences (AC vs JPL)

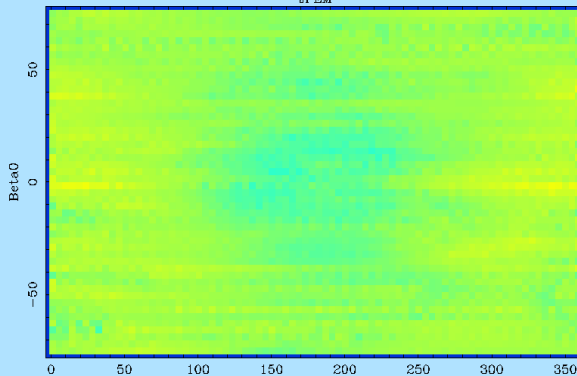
SP3 Orbit and Clock Differences

JPAI



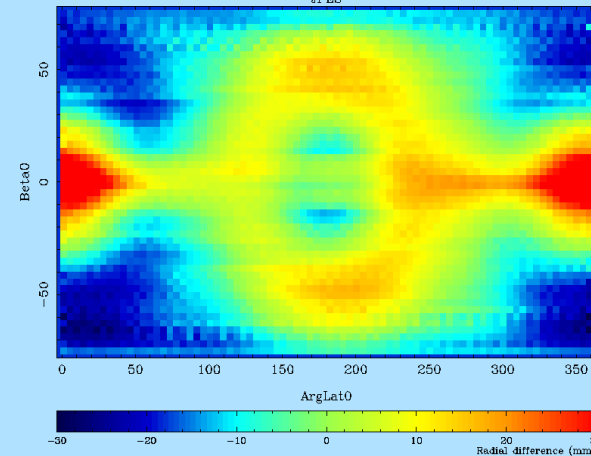
SP3 Orbit and Clock Differences

JPEM



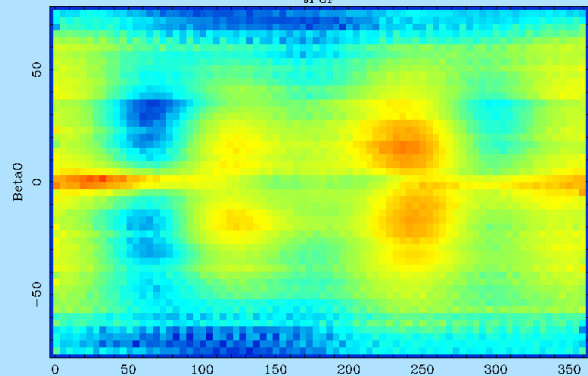
SP3 Orbit and Clock Differences

JPES



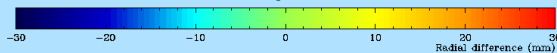
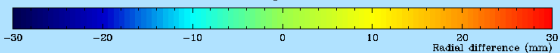
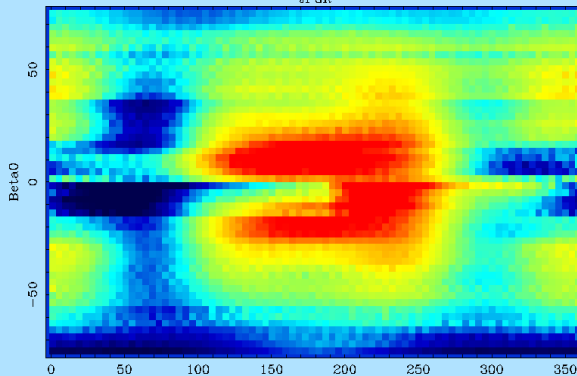
SP3 Orbit and Clock Differences

JPGF



SP3 Orbit and Clock Differences

JPGR



EMR JPL similar!

GFZ NGS MIT SIO and IGS similar

IIF Cross-track



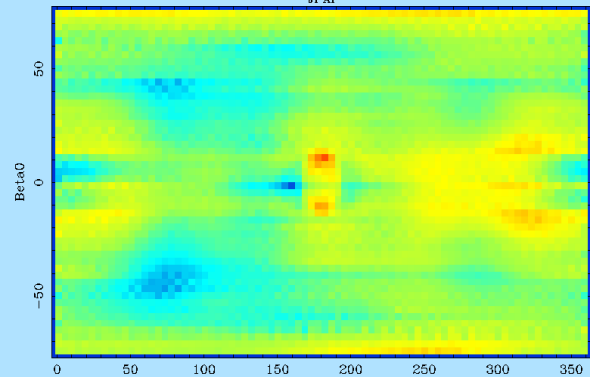
- Only ESA a bit off
- So skipping figures



IIR Radial Differences (AC vs JPL)

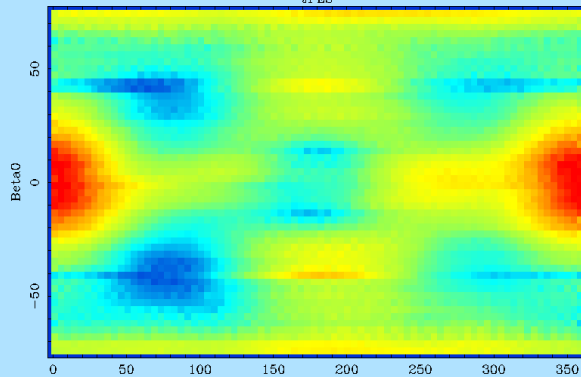
SP3 Orbit and Clock Differences

JPAI



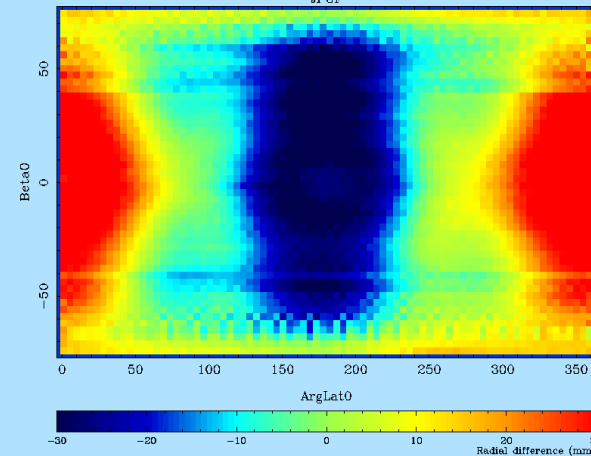
SP3 Orbit and Clock Differences

JPES



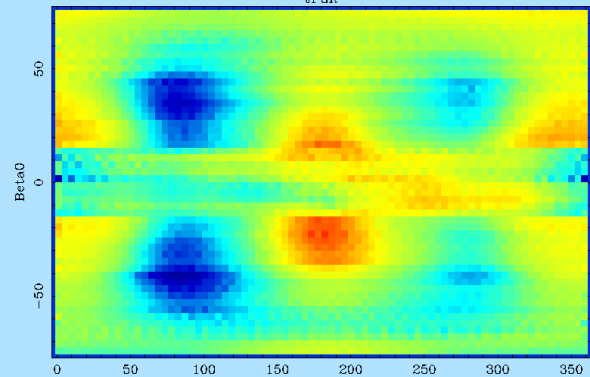
SP3 Orbit and Clock Differences

JPGF



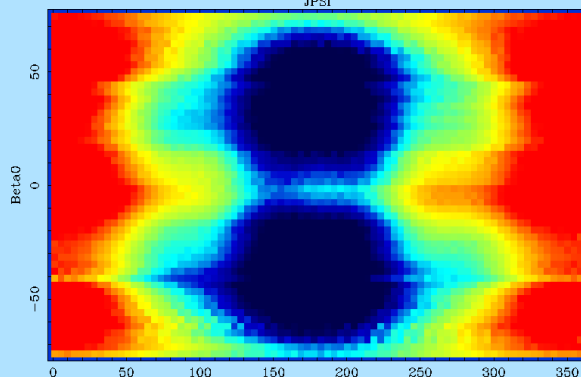
SP3 Orbit and Clock Differences

JPIR



SP3 Orbit and Clock Differences

JPSI

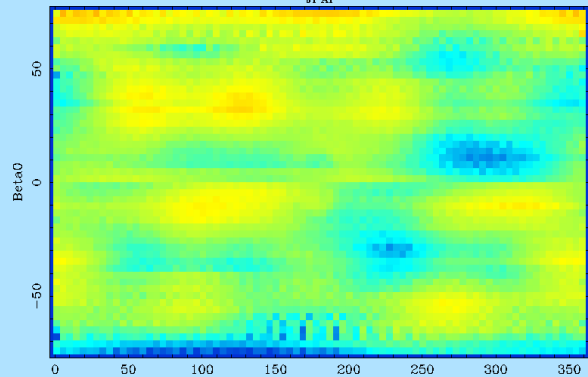


GFZ NGS MIT similar

IIR Cross-track Differences (AC vs JPL)

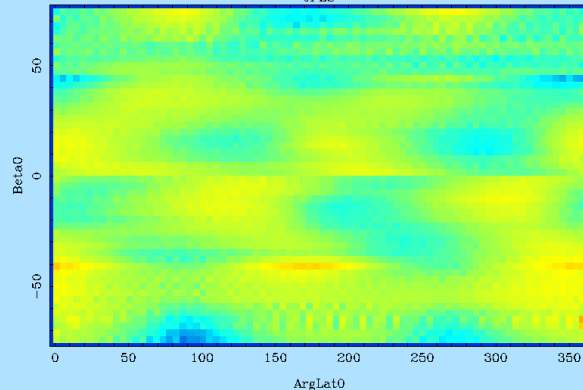
SP3 Orbit and Clock Differences

JPAI



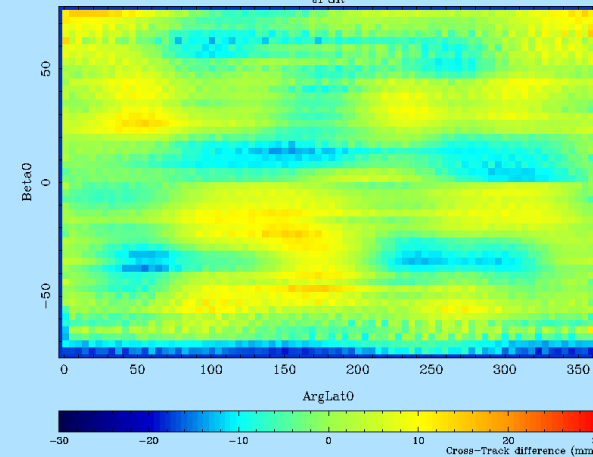
SP3 Orbit and Clock Differences

JPES



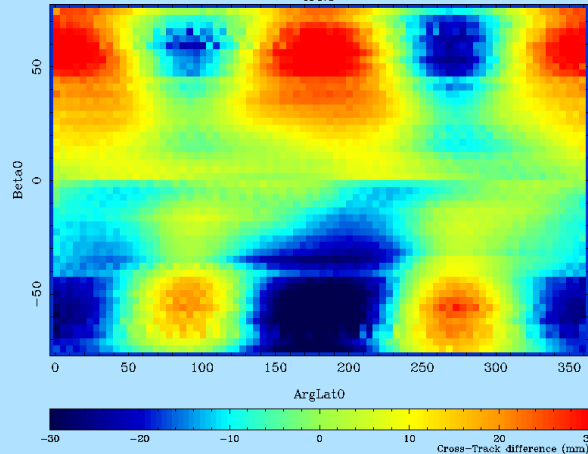
SP3 Orbit and Clock Differences

JPGR



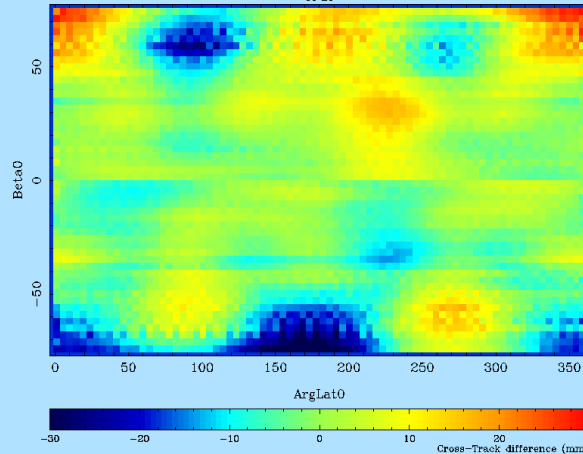
SP3 Orbit and Clock Differences

JPNO



SP3 Orbit and Clock Differences

JPSI

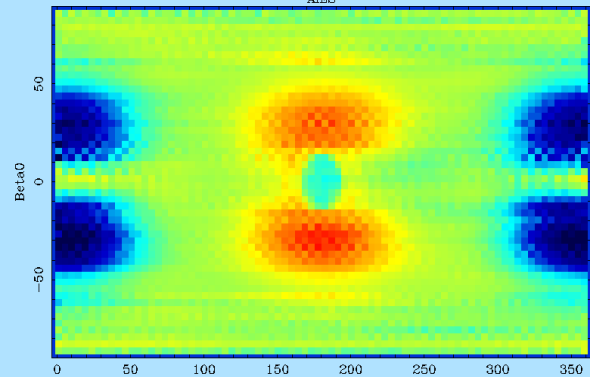


GFZ NGS MIT similar

GLONASS (AC vs COD)

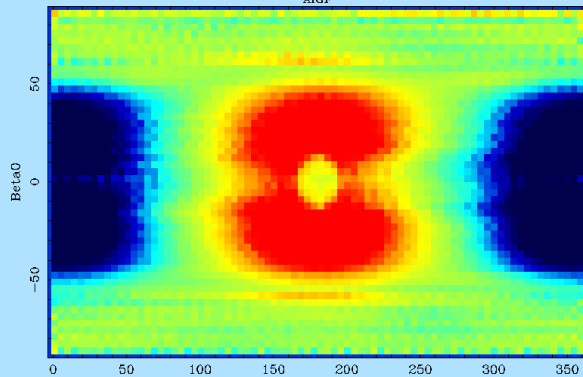
SP3 Orbit and Clock Differences

AIES



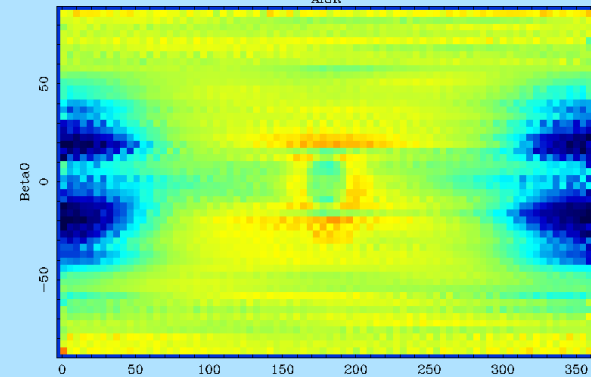
SP3 Orbit and Clock Differences

AIGP



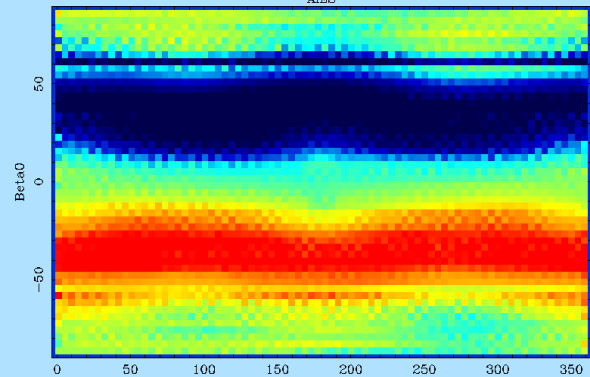
SP3 Orbit and Clock Differences

AIGR



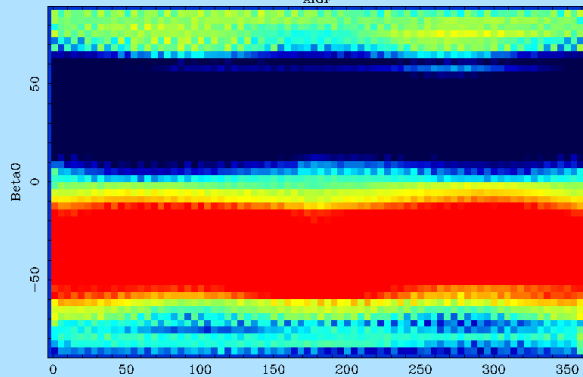
SP3 Orbit and Clock Differences

AIES



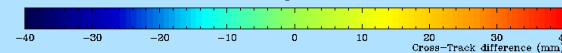
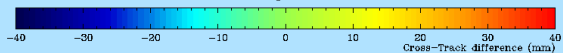
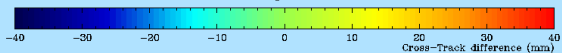
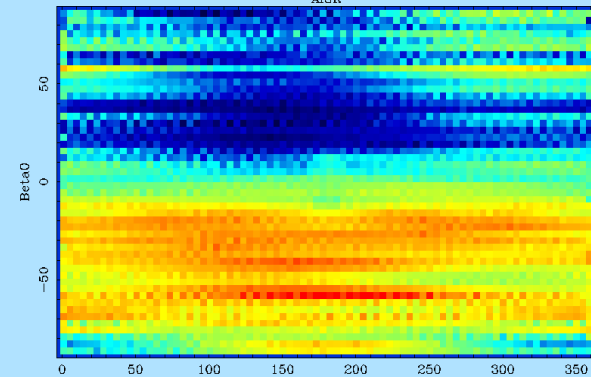
SP3 Orbit and Clock Differences

AIGP



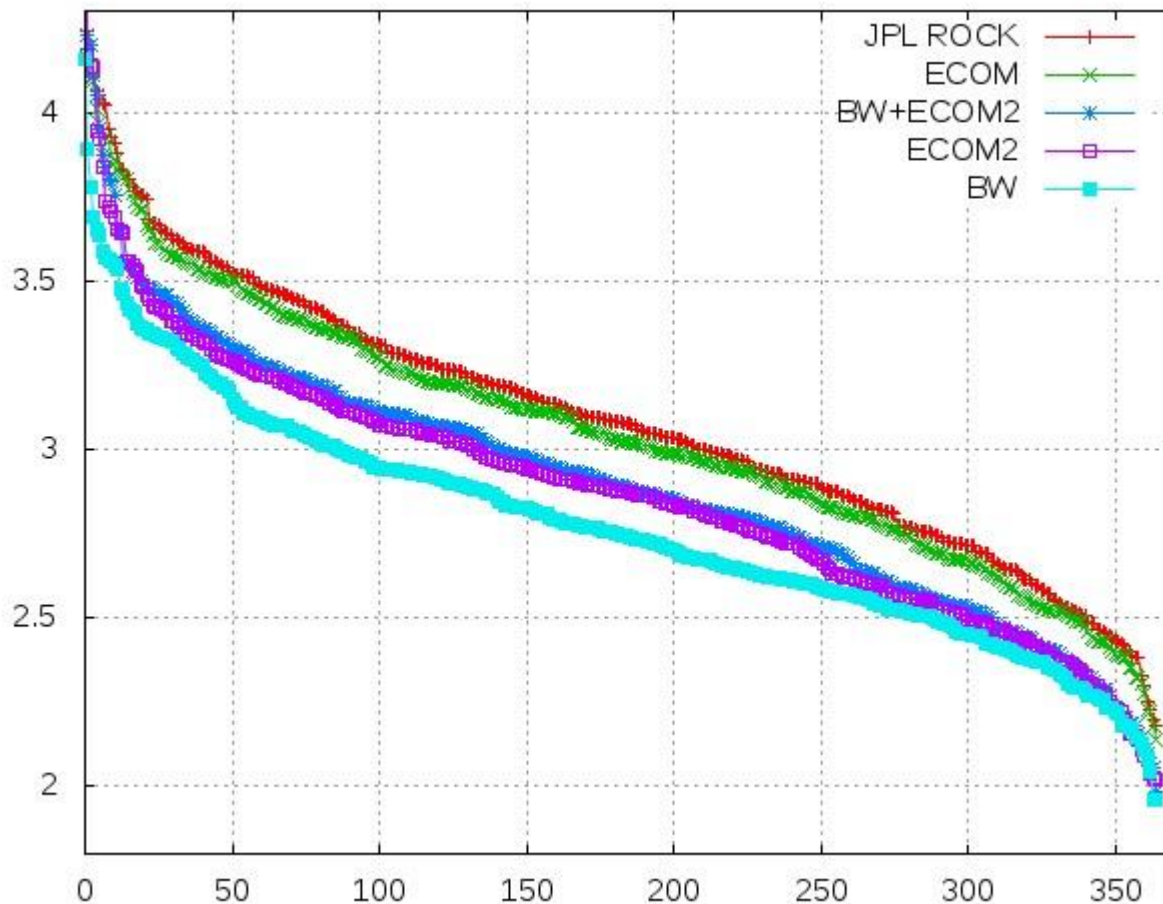
SP3 Orbit and Clock Differences

AIGR



- We observe some very significant differences
- Differences with IIF smaller than expected
- Differences with IIR larger than expected
- COD, ESA and JPL use “enhanced” models
 - For IIR these are in agreement, for IIF not
- Hard to tell which solution(s) are “better”
- To figure this out we made 5 test solutions emulating:
 - BW: Box-wing approach from ESA
 - BW+ECOM2: Using ECOM2 on top of box-wing as a priori model
 - ECOM: The classical 5 parameter set (D0, Y0, B0, BC, BS)
 - ECOM2: The new COD 7 parameter set (ECOM + DC2 +DS2)
 - JPL ROCK: Partial implementation of JPL model
- Note: Switch of model only for IIF satellites, ECOM2 when used for all satellites

Result



Conclusions



- Main conclusion at this point:
 - ESA IIF box-wing model is not OK
 - ECOM2 approach does not work for block IIF satellites
 - ECOM2 approach seems inadequate for GLONASS as well
 - ECOM seems to work fine for the IIF
 - JPL GSPM models looks very promising (even using just the ROCK part of it).

- For reprocessing we should also have a look at the II/IIA satellites



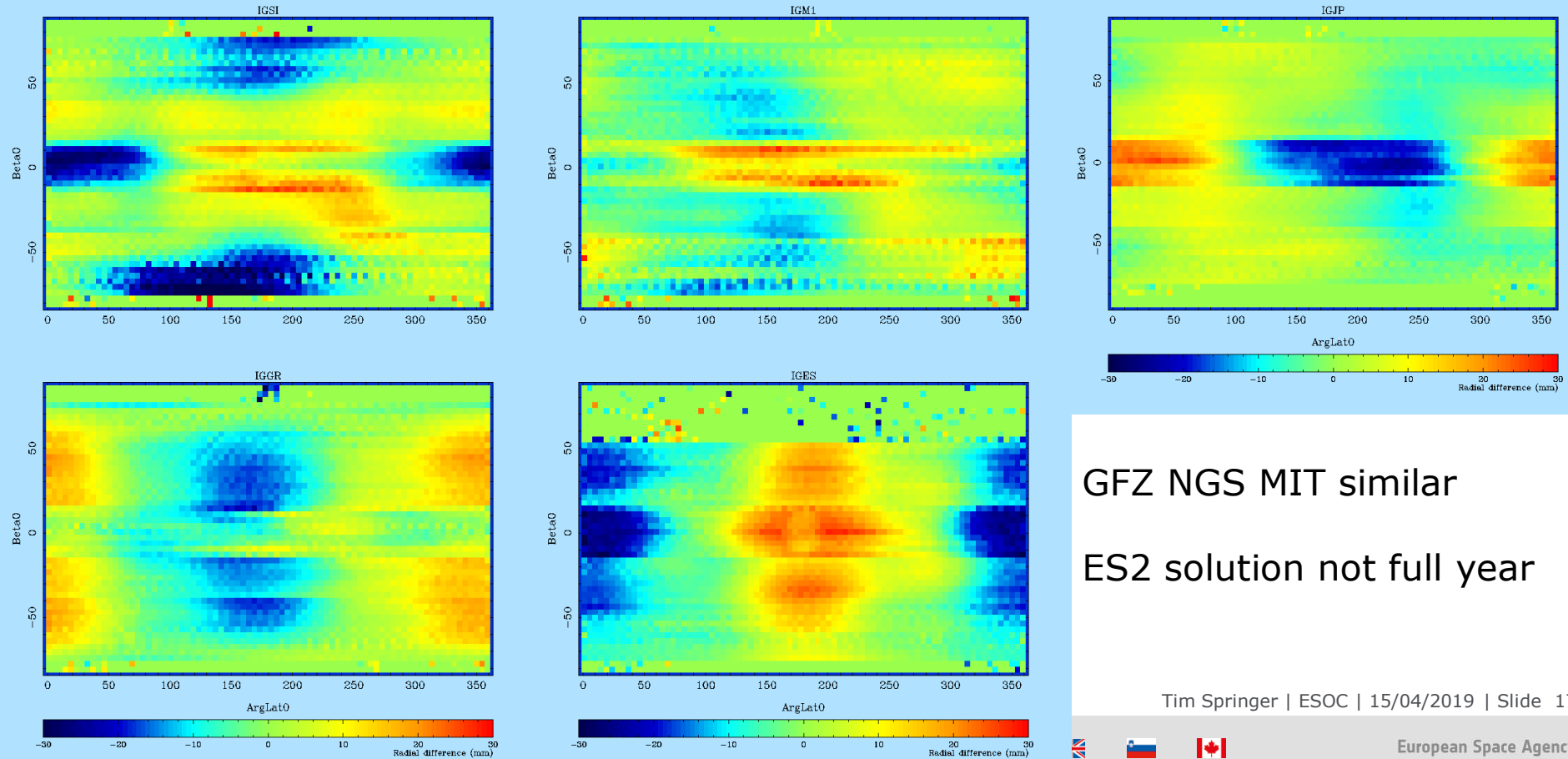
2014 Investigation



- Full year 2014
 - 7 block II/IIA satellites
 - 18 block IIR/IIRM satellites
 - 7 block IIF satellites
- All IGS Final and repro2 orbits available at CDDIS
- Compared in radial-, along-, and cross-track
 - Against IG2 Repro2 Final and against JPL
 - Compared separately per GPS block type
 - Block II/IIA considered as one type
 - GLONASS ignored
- 2014 was a bad choice! Last year of repro so many repro2 not there or only partially.
 - IIF are appearing in this year and have some issues
 - More useful to look at repro2 orbits than at the original ones. Repeat with 2013?



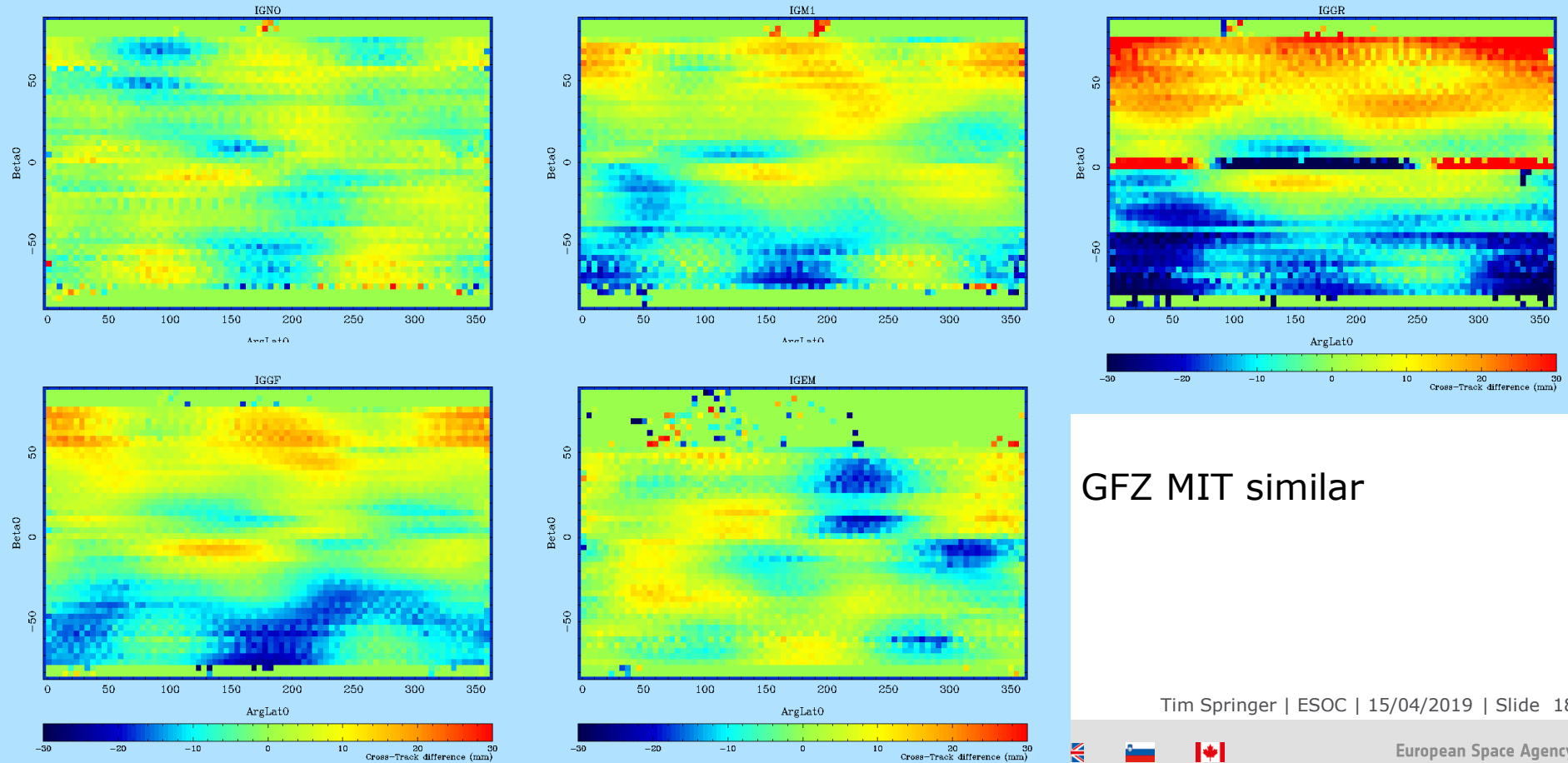
II/IIA Radial Differences (AC vs IG2)



GFZ NGS MIT similar

ES2 solution not full year

II/IIA Cross-track Differences (AC vs IG2)



GFZ MIT similar

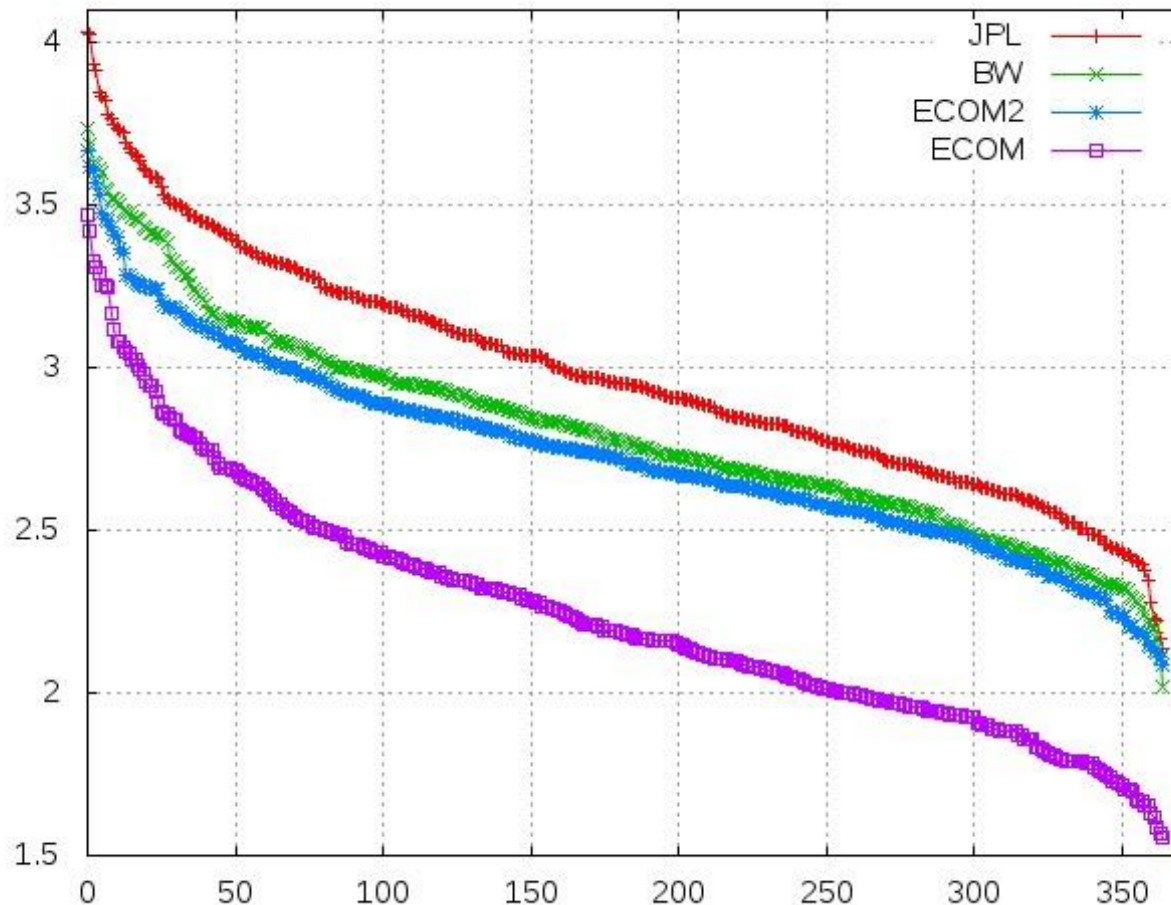
Discussion



- Similar results for IIR and IIF as observed in 2018
- Also significant differences for II/IIA but smaller than for IIR
- Made 4 test solutions to figure out what may be “best”:
 - BW: Box-wing model from ESA
 - ECOM: The classical 5 parameter approach (D0, Y0, B0, BC, BS)
 - ECOM2: The new COD 7 parameter approach (ECOM + DC2 +DS2)
 - JPL: Full implementation of JPL GSPM13b model
- In this case the models and approaches are used for all GPS satellite types
- All solutions used identical data. Only difference was the model or approach being tested

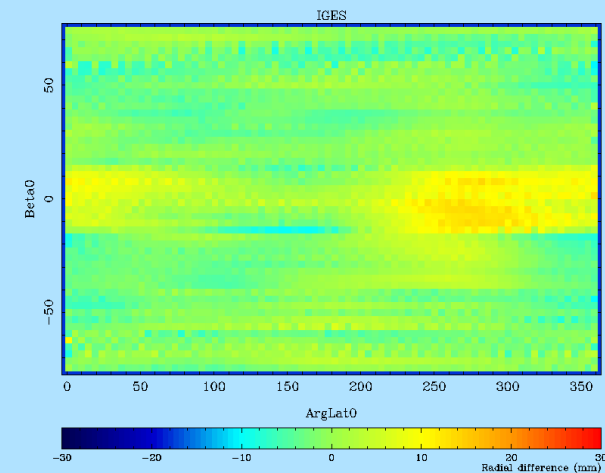
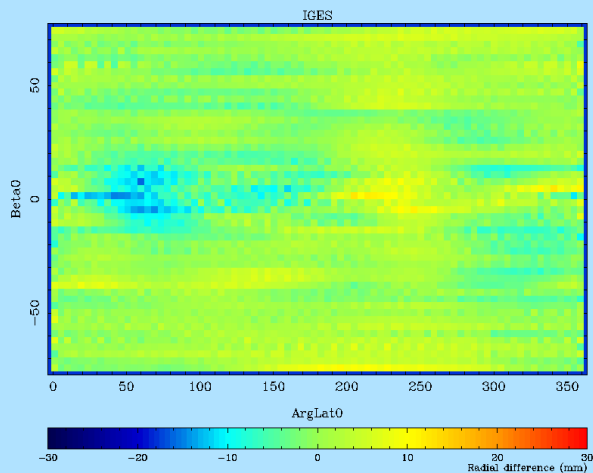
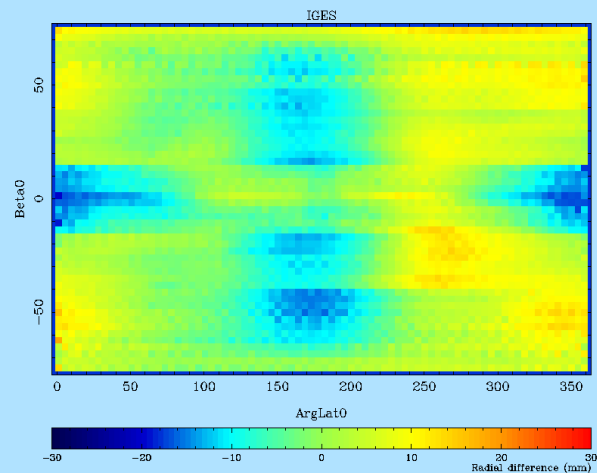
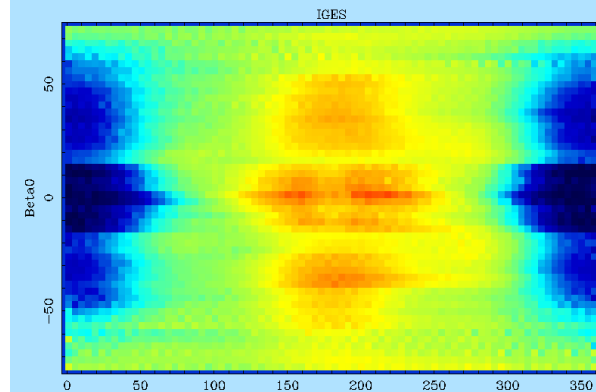


Result



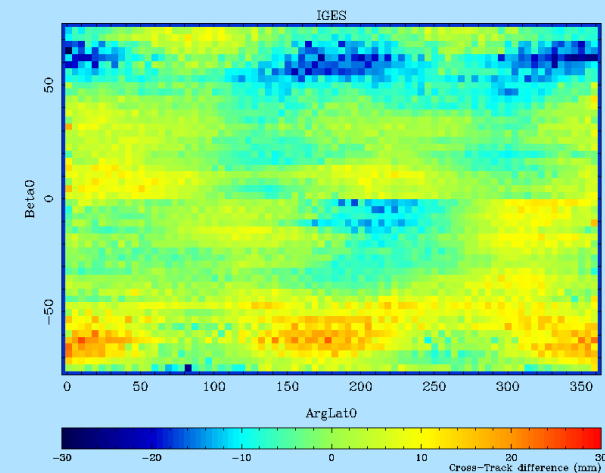
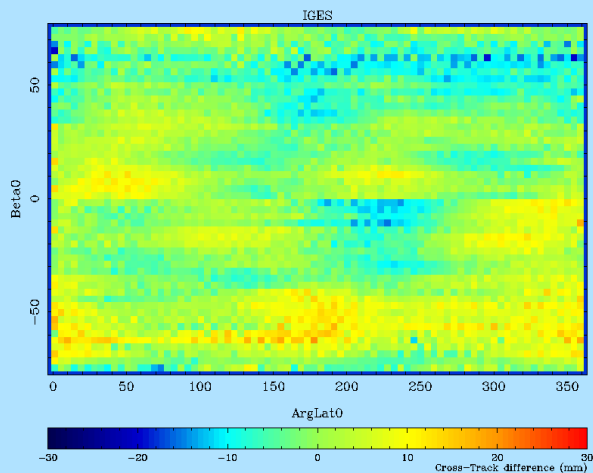
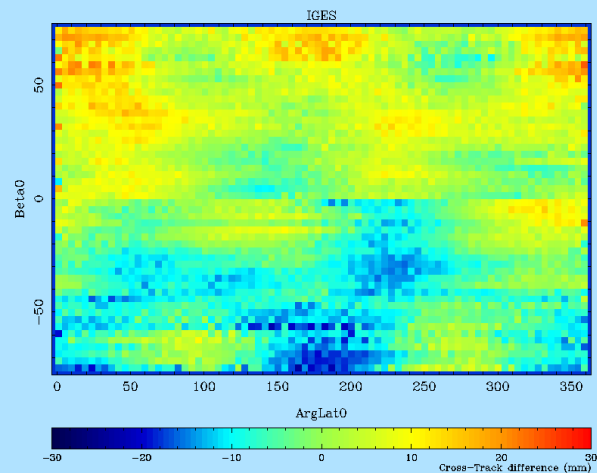
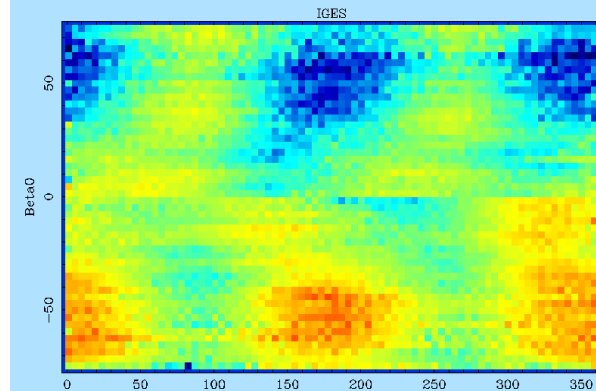
II/IIA Radial Differences (Test vs IG2)

- On the right: Box-wing
- Below from left to right: ECOM, ECOM2, JPL
 - Box-wing significantly different
 - SLR did proof box-wing?
 - ECOM a bit different!



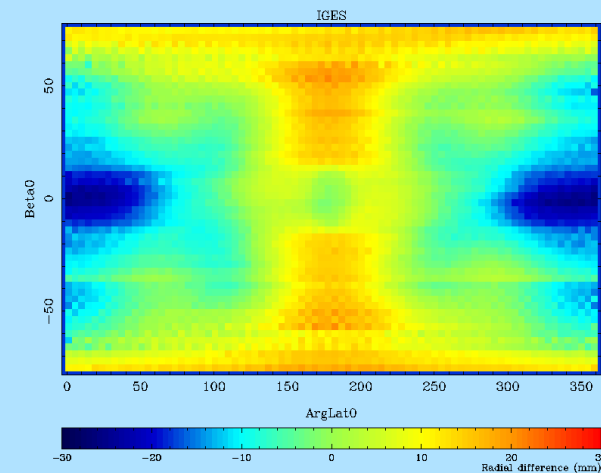
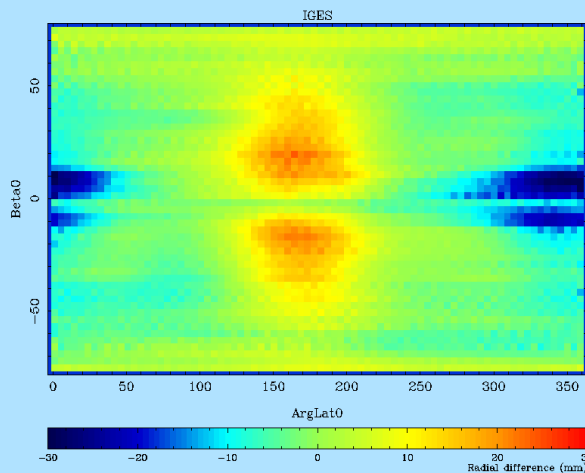
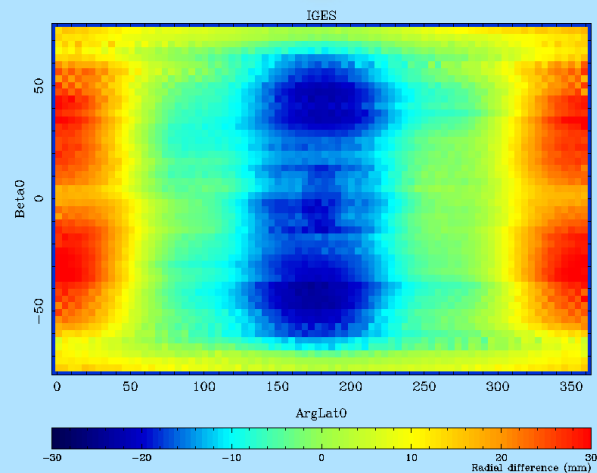
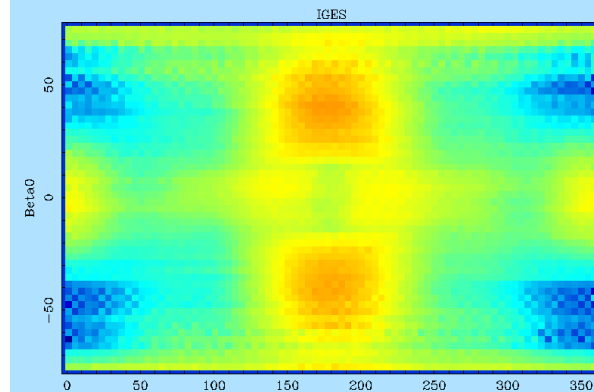
II/IIA Cross-track Differences (Test vs IG2)

- On the right: Box-wing
- Below from left to right: ECOM, ECOM2, JPL
 - ECOM a bit different!
 - Box-wing similar but stronger signal than JPL model



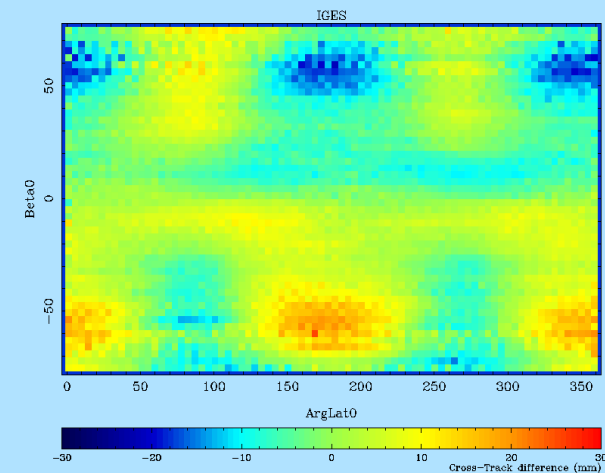
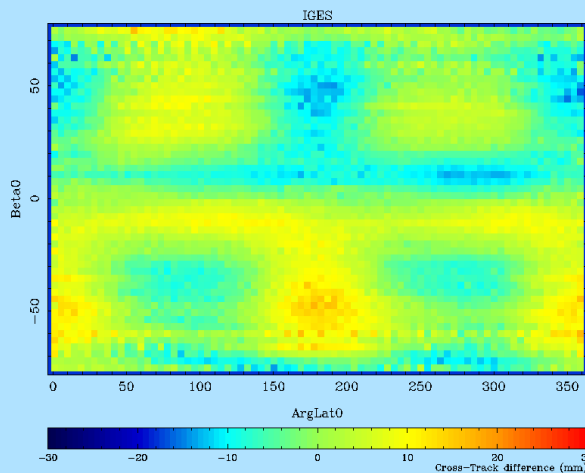
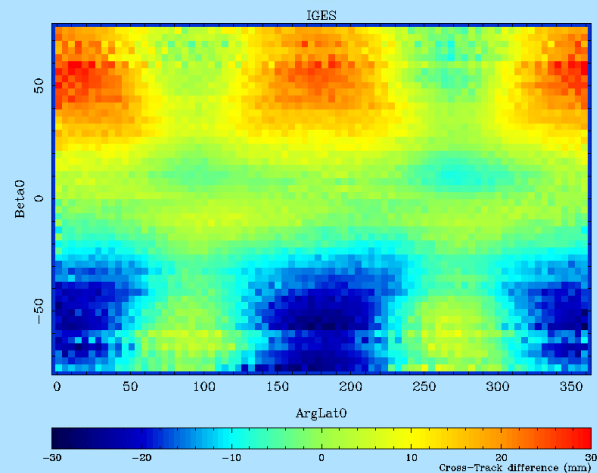
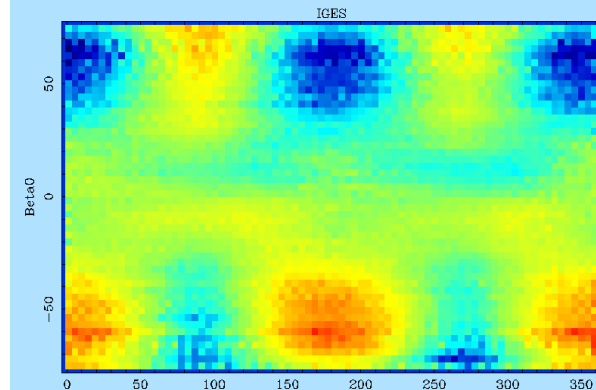
IIR Radial Differences (Test vs IG2)

- On the right: Box-wing
- Below from left to right: ECOM, ECOM2, JPL
 - ECOM significantly different

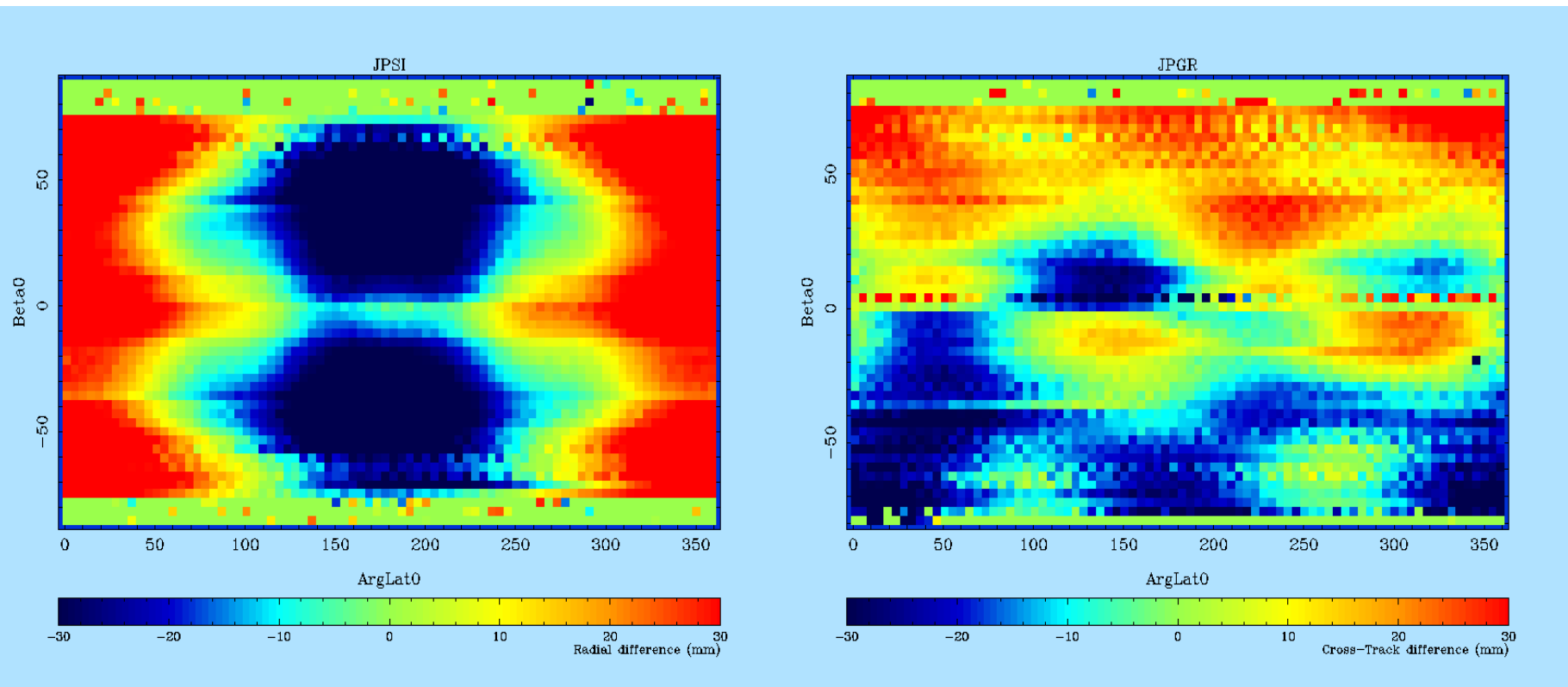


IIR Cross-track Differences (Test vs IG2)

- On the right: Box-wing
- Below from left to right: ECOM, ECOM2, JPL
 - Box-wing stronger signal than JPL model
 - ECOM significantly different



Most Extreme Cases



- If the kurtosis is indeed a good indicator of the orbit quality, as we believe it is, the kurtosis plot shows that the JPL GSPM model is doing an excellent job
- The ESA box-wing model, meanwhile tuned for the IIF satellites, and the ECOM2 approach both do a reasonable job but with some very significant differences between them and also when compared to the JPL GSPM model
 - Box-wing seems a bit off for II/IIA satellites
- Our “good old” ECOM approach performs relatively poorly. Although it seems to perform rather well for the IIF it does not do a good job for the IIR satellites. It is also questionable for the block II/IIA satellites by today's standards.

Conclusions

- JPL GSPM model works very well
- ESA box-wing model was not working very well for IIF
 - Meanwhile “tuned” model seems to perform OK
 - Seems to have some issues with II/IIA as well
- ECOM2 model does not work well for the IIF
 - May also have issues with GLONASS
- ECOM model clearly fails to model the IIR satellites adequately!
 - Also not great for II/IIA, but good for IIF
- SIO IIR radial very different
- GRGS IIA cross very different

Due to highly systematic nature of these differences they hardly show up in the RMS differences of orbit comparisons

- The JPL GSPM model may be used for all GPS satellites
 - Not available for GLONASS?
- ECOM2 is certainly to be preferred over the ECOM approach
 - Some issues for the IIF
 - Not optimal for GLONASS
- IGS/ESA box-wing approach also better than ECOM
 - For those who used it for Earth Albedo (and IR?) it should be easy to do
- All three models will still result in draconic periods in the IGS products

Much more effort needs to be put into improving the RPR modeling of the GNSS satellites to reduce the spurious draconic terms in the IGS products!