The ESA/ESOC Analysis Center Progress and Improvements

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Abstract

ESA/ESOC is a very active Analysis Centre within the IGS and it is providing excellent products to the IGS. This poster presents the quality and consistency of the ESA products over the last years. Main topics that will be addressed are:

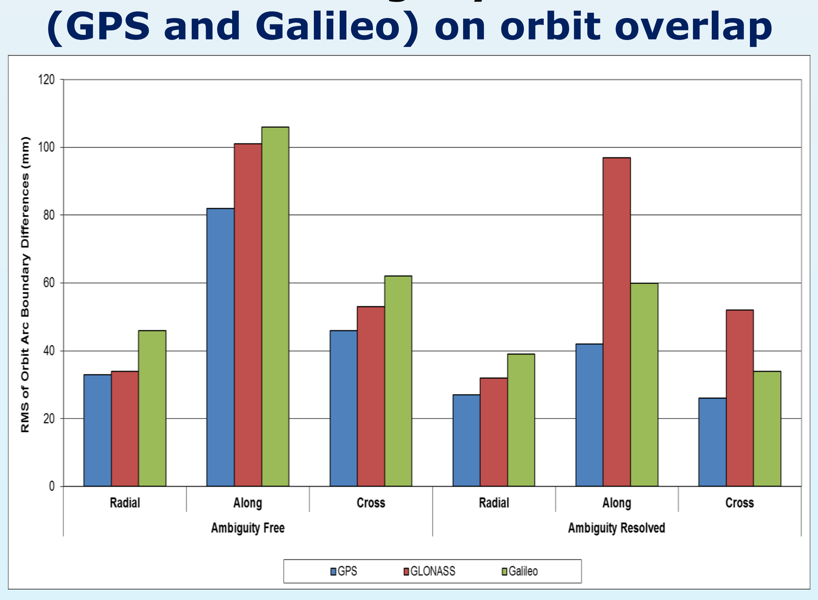
Multi-GNSS

The modernization of the existing and the deployment of new Global Navigation Satellite Systems introduces new satellites, new orbits, new code modulations and additional frequencies. Improvements in the IGS products will strongly depend on our understanding of these new systems. We are focusing on: satellite force models, handling of different attitude modes, satellite PCO/PCV values, and the handling of the different signals and biases.

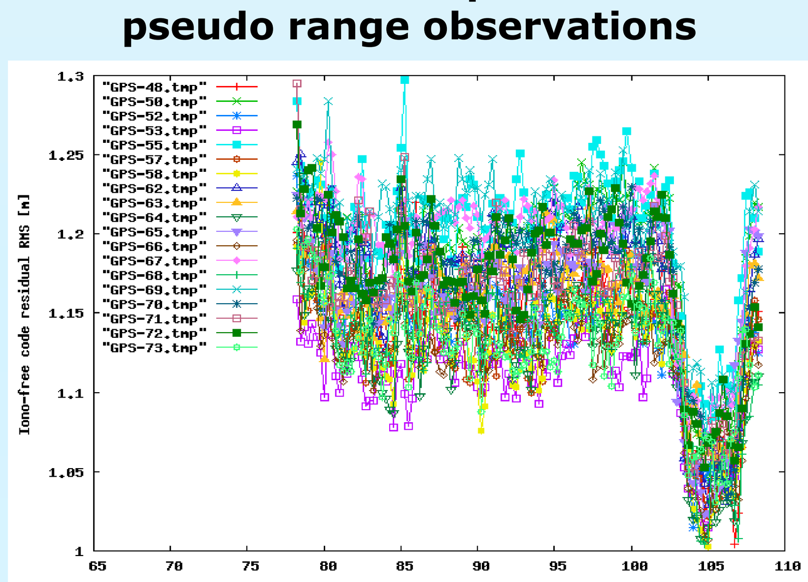
Orbit Modelling

The new GNSS satellites, GPS IIF, Galileo, BeiDou, QZSS, are posing some interesting new challenges. The key issue here is the increasing area to mass ratio of the satellites which makes them more sensitive to the radiation pressure. The different attitude modes that are being used to handle the satellite eclipse phase are posing some new and interesting challenges.

Effect of Ambiguity Resolution (GPS and Galileo) on orbit overlap



Effect of GPS Flex-power on the pseudo range observations



ESA/ESOC GNSS Activities

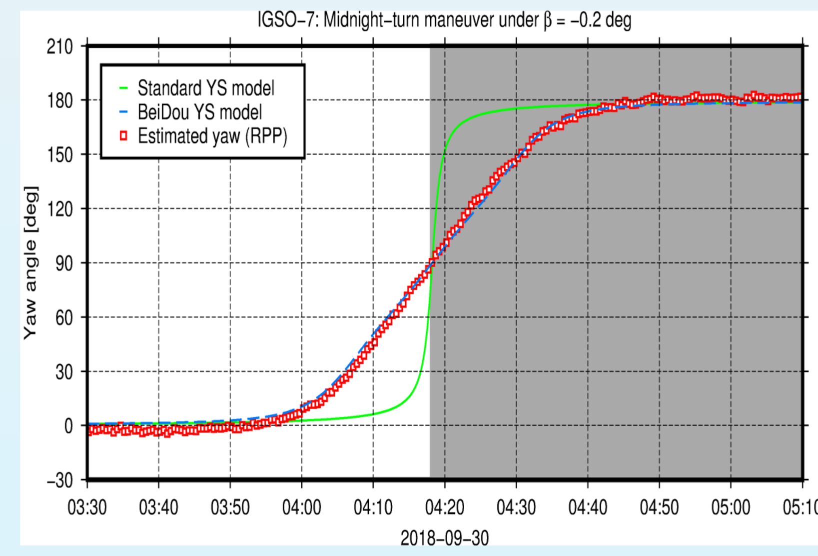
We closely monitor the quality of all our different ESA GNSS solutions to capture all unexpected events and/or overlooked side effects of model changes.

We are preforming integer ambiguity resolution for GPS, Galileo, BeiDou and QZSS. This is reflected by a significant improvement of the orbit overlap statistics (plot top left).

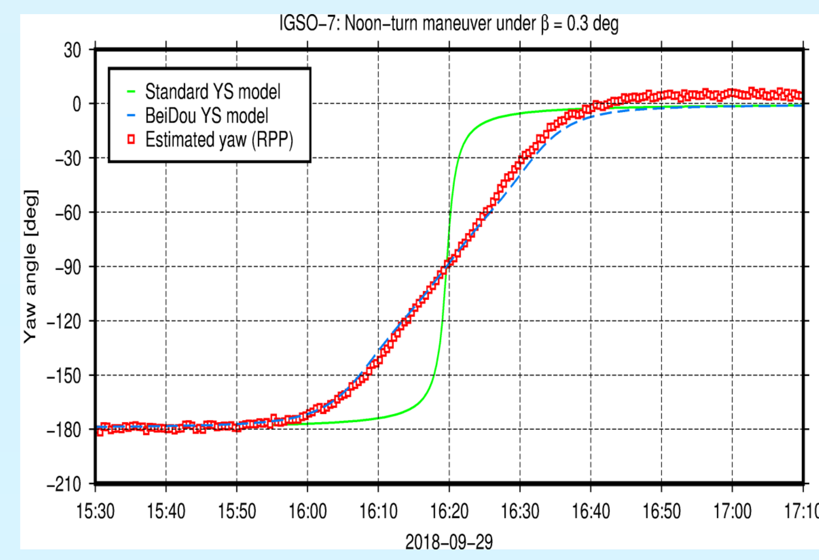
Earlier this year the GPS system did activate its flex power ability. Although this did not affect the quality of our GPS products it did significantly affect the pseudo range observations (plot bottom left). Also some receivers failed during this event. So flex-power is something the IGS should monitor.

In the last years the several BeiDou satellites have moved away from going into "orbit normal mode" during the eclipse season. They now stay in "yaw steering mode" similar to what the other GNSS systems do (plots on the right). Most recently BeiDou C16 used the yaw steering mode during its most recent eclipse season.

BeiDou Yaw Steering from Reverse PPP



Top: Midnight Turn
Bottom: Noon Turn



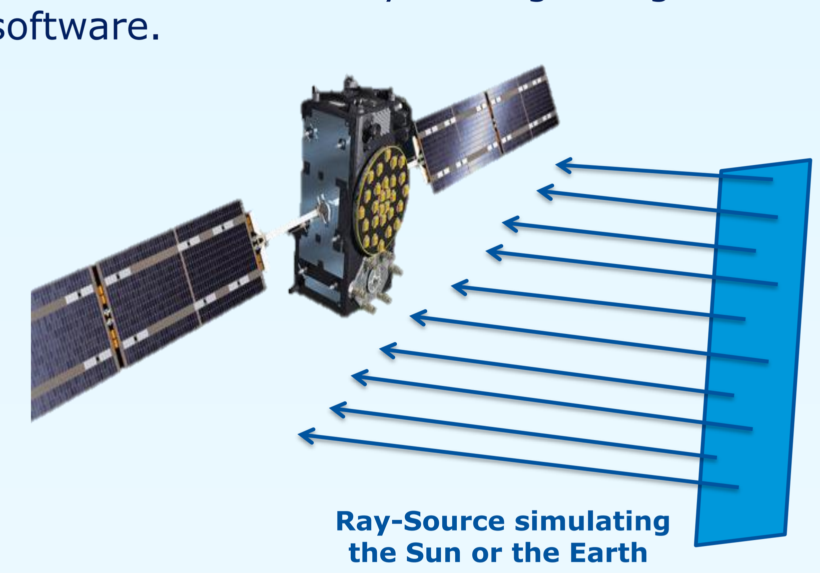
Radiation Pressure Modelling

Almost three decades ago Henry Fliegel wrote on the radiation pressure force model of the GPS satellites:

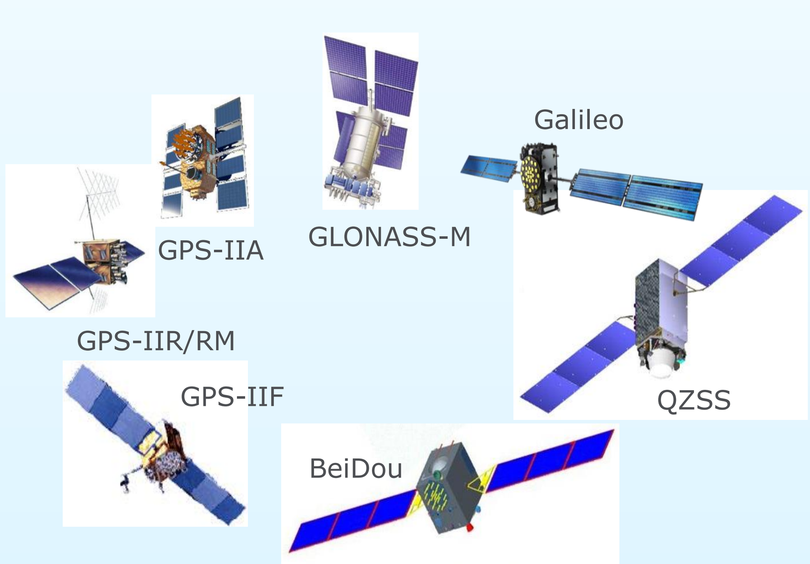
"To generate the highly precise ephemerides of Global Positioning System satellites necessary for modern geodetic applications, one must have an accurate force model that includes the pressure of solar radiation and spacecraft thermal emission"

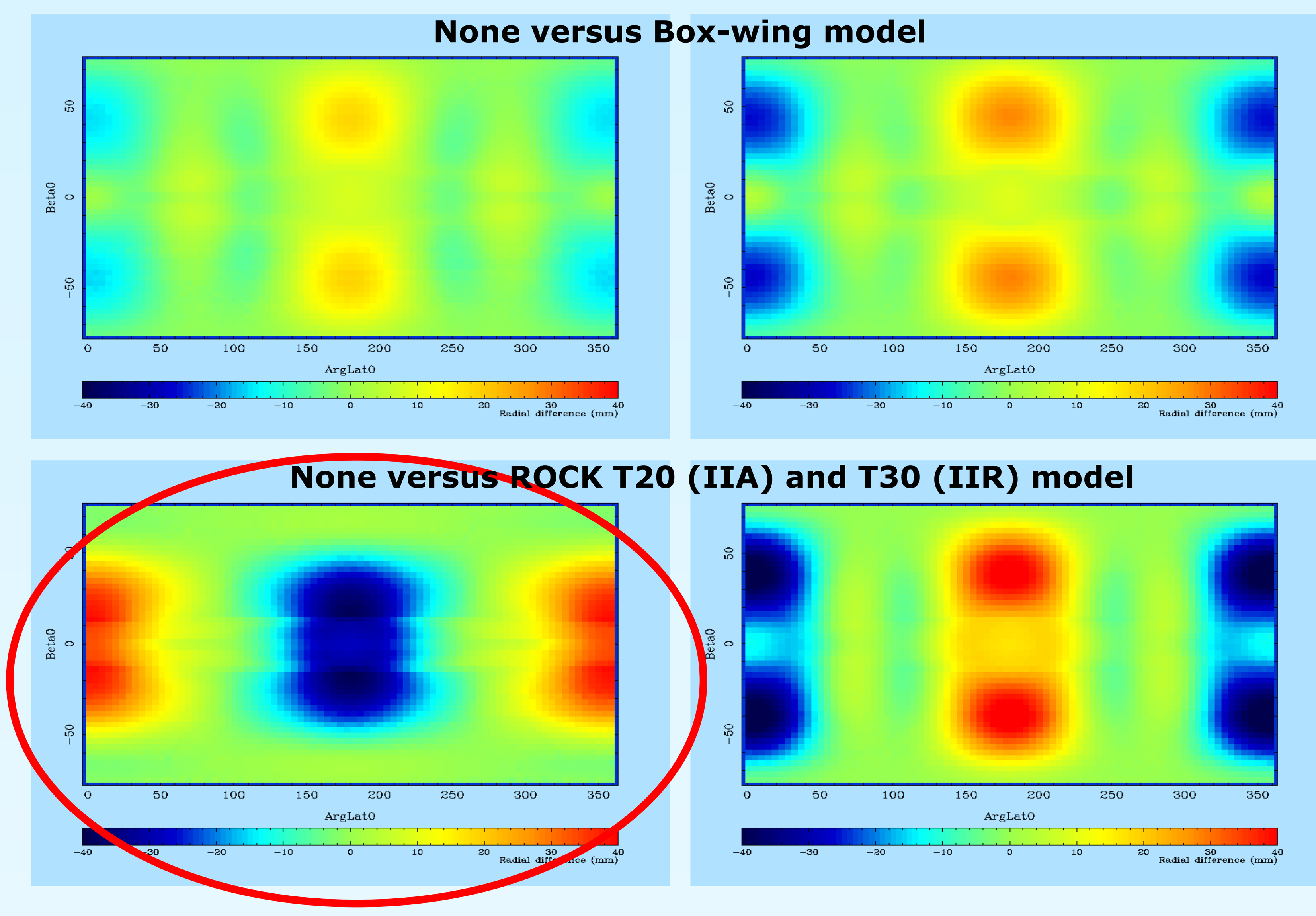
ESA/ESOC Next Step: Ray-Tracing

We have extended our activities in this area now moving on from the relatively simple box-wing modelling to much more detailed models based on ray-tracing using the ARPA software.



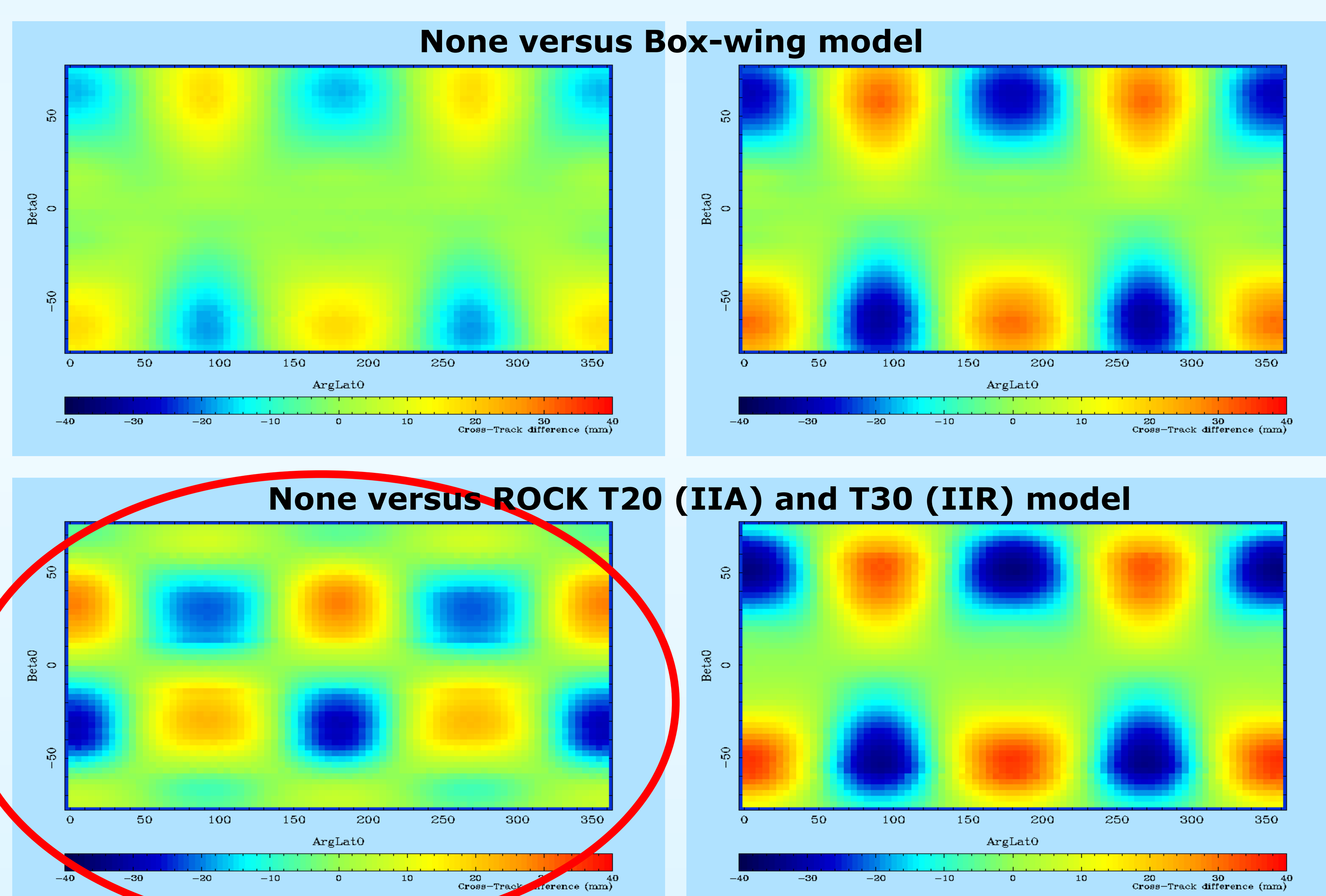
Given the complex shapes of the GNSS spacecraft's we believe that the ray-tracing models should perform significantly better then the simple, but effective, box-wing models we have been using until now.





Above: IIA Radial difference
Below: IIA Cross-track difference

Above: IIR Radial difference
Below: IIR Cross-track difference



Rock model revisited

We have done significant work in this area in the last years and have shown the importance of an accurate, or at least adequate, radiation pressure model for GPS, GLONASS, and Galileo in particular. Our GPS box-wing models are in principle based on the information contained in the Fliegel papers. This raises the question why the ROCK model T20 failed where the box-wing model works!?

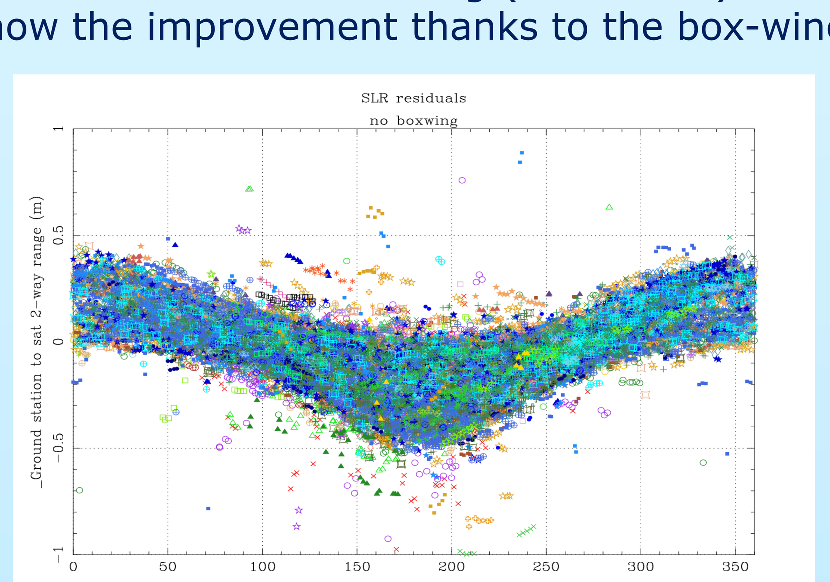
To try and understand this we made a simple yet effective and in our opinion representative test. We used a full year of reprocessed orbits and made 3-day orbit fits using the satellite positions as pseudo observations. For each satellite the state vector and the 9 parameters of the ECOM model were estimated. Three different solutions were generated, one using no apriori model, one using our box-wing models as apriori model, and one using the ROCK models as apriori model. ROCK T20 for the GPS block II/IIA satellites and ROCK T30 for the block IIR satellites. The resulting fitted orbits were compared with each other in the radial, along-, and cross-track directions. We used the results without any apriori model as reference and compared the box-wing and ROCK model results to these "reference" results. We did this separately for the block II/IIA and block IIR satellites. The resulting differences are shown here on the right for the radial and cross-track differences. Along-track is much less interesting.

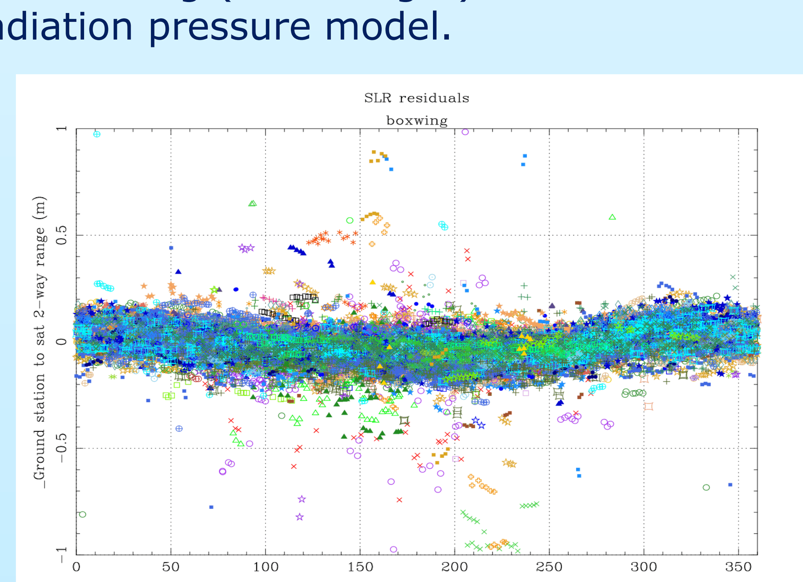
The two plots with the red circles highlight the results for the block IIA satellites with the ROCK T20 model. They are clearly very different from the other results. Given that shape wise the block II/IIA and IIR satellite are both pretty much square boxes one would expect the signature of the radiation pressure accelerations to be rather similar. For the box-wing results we can see that this is the case. But for the ROCK model results this is clearly not the case.

Our conclusion is that something went wrong in the generation of the ROCK T20 model whereas the ROCK T30 results show that the software that was used to generated the ROCK models can generate good results. We did also use the ROCK T30 model in a full year of reprocessing and the results were comparable to the box-wing results.

SLR Validation

The availability of SLR reflector arrays on most of the GNSS satellites, with the notable exclusion of GPS, allows the completely independent validation of the GNSS orbit quality by means of the SLR observations. The two plots below show the validation of our Galileo orbit estimates without box-wing (on the left) and with box-wing (on the right). The results clearly show the improvement thanks to the box-wing radiation pressure model.





Conclusions

- The ESA/ESOC Analysis Center remains fully dedicated to the IGS
- Despite 20 years of service still significant progress can be made
- Radiation pressure modelling getting more and more important as the GNSS satellites getting both larger and lighter and the area to mass ratio is one of the critical issues. The other issue is the area ratio of the X and Z surfaces.
  - Moving to ray-tracing technique using the ARPA software
    - PhD work of F. Gini, at ESOC and Univ. Padova
  - Initial models for Galileo generated
  - Initial model for QZSS generated, next steps in preparation
- Also review ROCK and JPL type of models because of ease of use and in the JPL approach no need for information about the satellite

European Space Agency