

IGS Multi-GNSS Working Group Splinter Meeting

Wednesday, 26 April 2016, 08:30-10:00 (Room 2.17)

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DLR, German Space Operations Center

- Advance and harmonize models for multi-GNSS orbit and clock products
 - Attitude models
 - Antenna models
 - (Solar) radiation pressure models

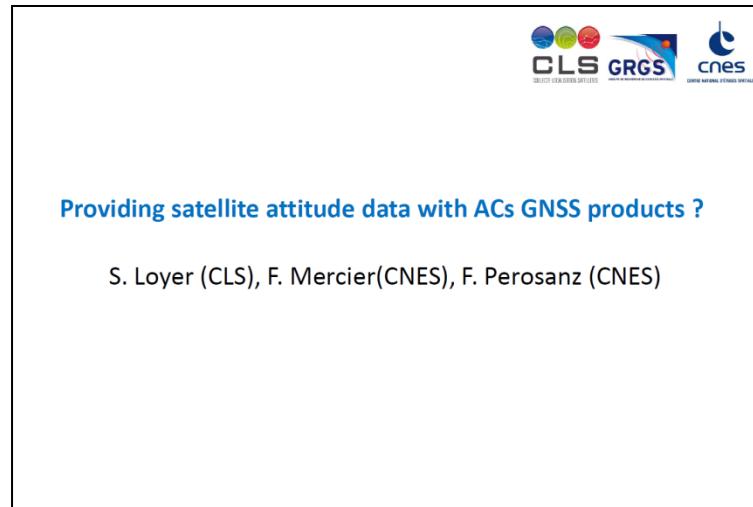
(Note: triggered by, but not limited to release of Galileo metadata)
- Consolidate/promote meta new formats
- Establish new product naming conventions

Part 1

Attitude Models

Attitude Data Product

- Various attitude models (GPS, GLO, GAL) published for eclipse phases
- Need to ensure consistency between product provider and PPP user
- Proposal: dedicated product for provision of attitude data as used in orbit/clock computation
- See separate handout by CNES/CLS AC

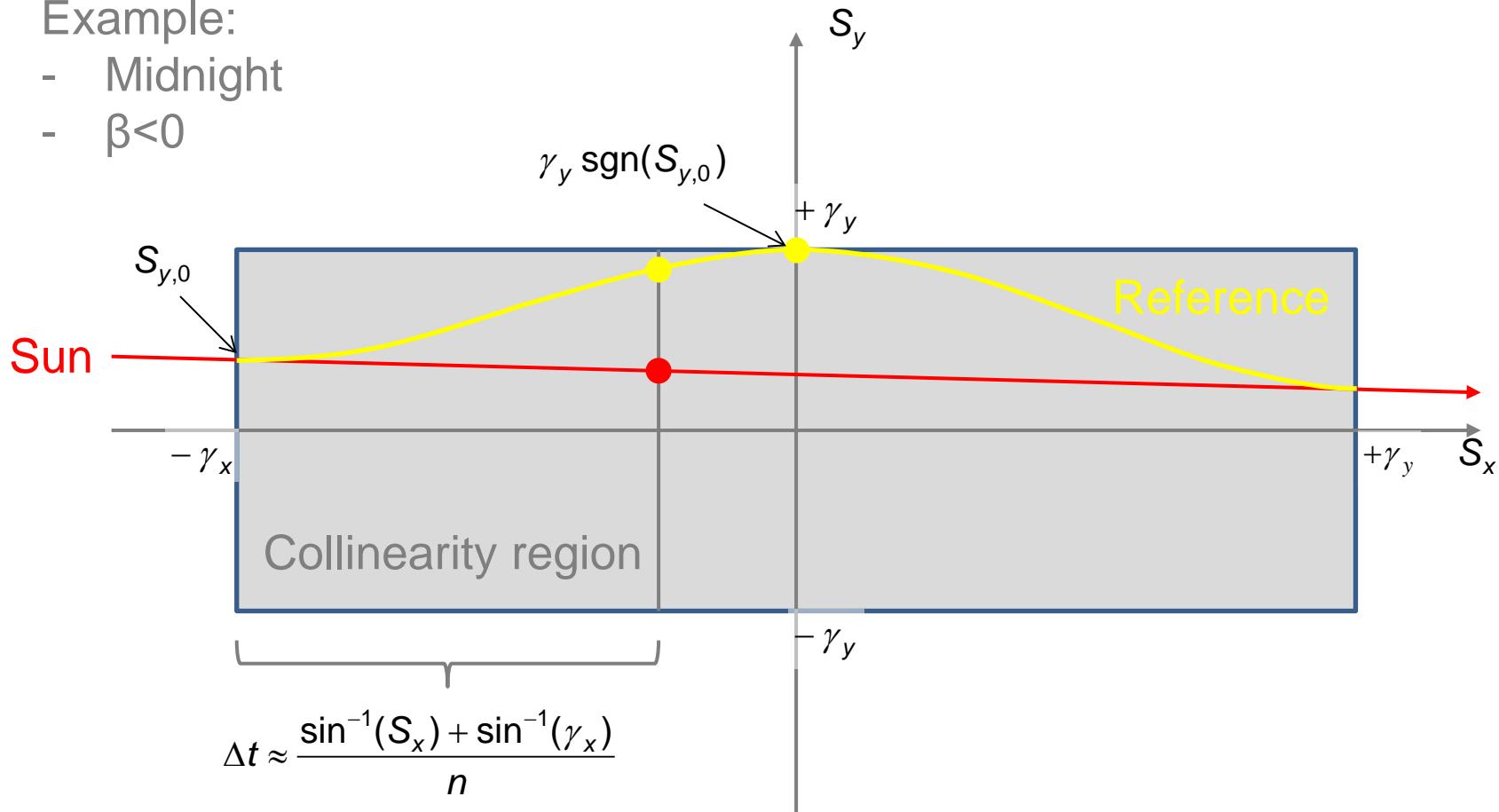


- Description of Galileo eclipse attitude provided along with satellite meta data in Dec. 2016
<https://www.gsc-europa.eu/support-to-developers/galileo-iov-satellite-metadata>
- Differs from previous assumptions (EADS patent)
- Experience?
- Issues?
- Galileo FOC?

Reference Sun Vector (Example)

Example:

- Midnight
- $\beta < 0$



Galileo Attitude Law - Formulation

- True Sun direction unit vector in orbit-normal frame

$$\mathbf{S} = \begin{pmatrix} S_x \\ S_y \\ S_z \end{pmatrix} = \begin{pmatrix} +\cos\beta\sin\mu \\ -\sin\beta \\ +\cos\beta\cos\mu \end{pmatrix} = \begin{pmatrix} -\cos\beta\sin\eta \\ -\sin\beta \\ -\cos\beta\cos\eta \end{pmatrix}$$

β Sun elevation above orbital plane
 μ Orbit angle from midnight
 η Orbit angle from noon ($=\mu+\pi$)

- Modified yaw-steering in collinearity region near noon/midnight
- $|S_x| < \gamma_x$, $|S_y| < \gamma_y$ ($\gamma_x = \sin 15^\circ$, $\gamma_y = \sin 2^\circ$)
- “Tweaked” Sun vector for yaw-steering

$$\overline{\mathbf{S}}_y = 0.5 \cdot (1+c) \cdot \gamma_y \operatorname{sgn}(S_{y,0}) + 0.5 \cdot (1-c) \cdot S_y \quad S_{y,0} = S_y \text{ at entry into collinearity region}$$
$$c = \cos\left(\pi \frac{|S_x|}{\gamma_x}\right)$$

Cosine weighting factor
(+1 at noon/midnight, -1 at transition)

$$\overline{S}_x = S_x$$

No change of x-component

$$\overline{S}_z = \sqrt{\overline{S}_x^2 + \overline{S}_y^2}$$

Normalization

$$\overline{\mathbf{S}} = \begin{pmatrix} \overline{S}_x \\ \overline{S}_y \\ \overline{S}_z \end{pmatrix} \quad \text{with}$$

Galileo Attitude Law – Issues

- Collinearity region is normally entered $\sim 35^m$ before noon/midnight and left $\sim 35^m$ thereafter
- Continuity of true and reference Sun vector ensured at entry, but not necessarily at exit
- Non-zero Sun elevation rate $dS_y / dt \approx \dot{\beta} \approx 0.05^\circ/h$
 - Sun may exit the collinearity region at top or bottom, i.e. $S_x \neq +\gamma_x$
 - Small discontinuity may occur since $c \neq -1$, $S_y \neq S_{y,0}$
 - Neglect? What about the real satellite?
- How to determine entry into collinearity region?
 - Test permanently and store true entry time?
 - Approximate entry time, e.g. $\Delta t \approx (\sin^{-1}(S_x) - \sin^{-1}(\gamma_x)) / n$ before current epoch, i.e. $\Delta t \approx \sin^{-1}(\gamma_x) / n$ before midnight?
- If Sun elevation is near zero at entry into the collinearity region, the tweaked Sun might have a different sign than computed onboard – how would we know?

Providing satellite attitude data with ACs GNSS products ?

S. Loyer (CLS), F. Mercier(CNES), F. Perosanz (CNES)

Background

Jan Kouba⁽¹⁾ and others (e.g Florian Dilsser⁽²⁾) did a huge work providing models & routines for attitude at the time of repro2 computations and later and Jim Ray⁽³⁾ pushed at that time to have a discussion on the subject of common attitude law.

But in practice ACs do not have always same attitude laws. The situation is complicated by the increase of constellations (MGEX), the generation of satellites (IIR/IIF, IOV/FOC,) and the increasing number of existing attitude laws (see O. Montenbruck review, 2015⁽⁴⁾).

Attitude as a geometrical effect on CoM-PCO vector and on the computation of Phase wind up corrections (visible on clocks differences).

Examples on next slides show that today MGEX ACs attitude modelling differs (for Glonass GPS & Galileo).

(1) Kouba, J (2008) A simplified yaw-attitude model for eclipsing GPS satellites GPS Solutions 2008: DOI:10.1007/s10291-008-0092-1

(2) "yaw attitude variations" at <http://acc.igs.org/reprocess2.html>

(3) Dilssner F (2010), GPS IIF-1 Antenna Phase Center and Attitude Modelling, Inside GNSS, September,59-64

Dilssner F, T Springer, G Gienger and J Dow (2010) The GLONASS-M satellite yaw-attitude model,Advances in Space Research (COSPAR) doi:10.1016/j.asr.2010.09.007

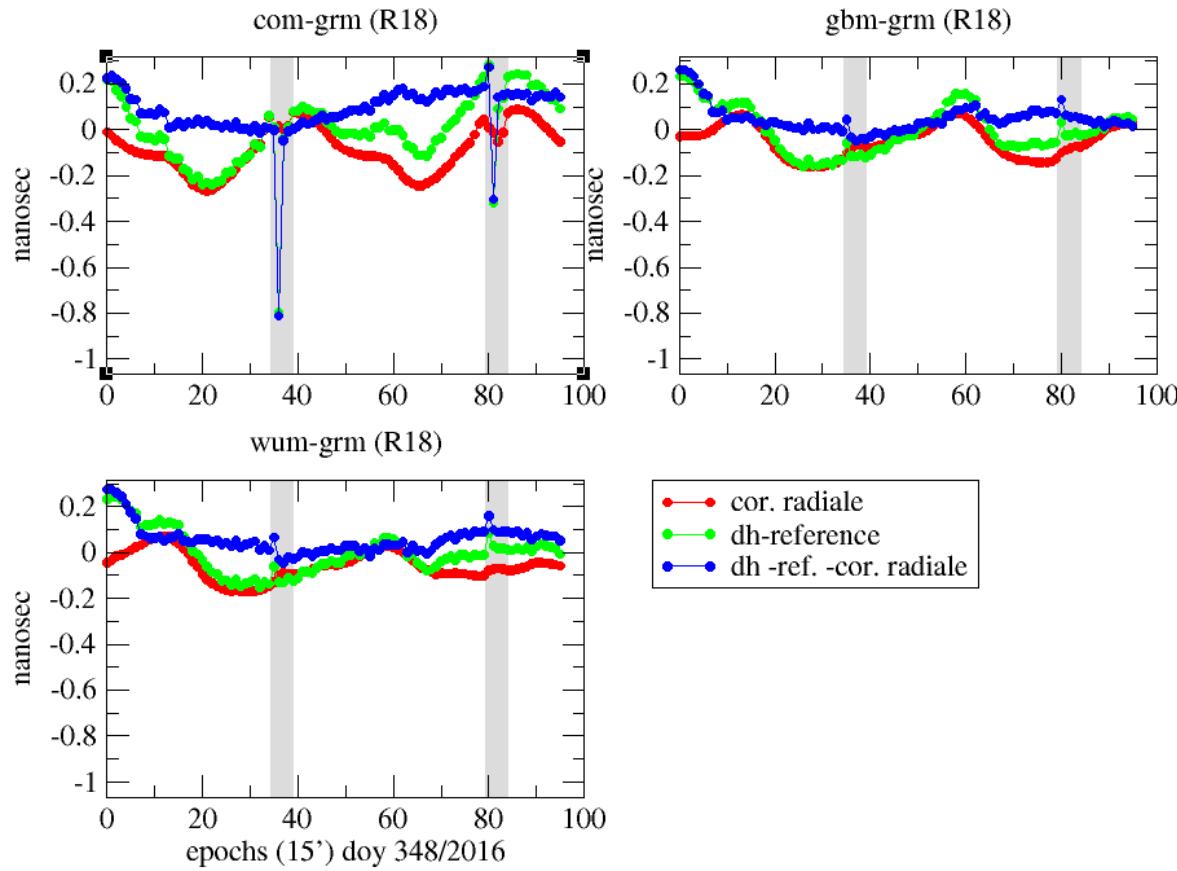
(4) Montenbruck et al., 2015, O. Montenbruck, R. Schmid, F. Mercier, et al. GNSS satellite geometry and attitude models, Adv. Space Res., 56 (6) (2015), pp. 1015–1029

<http://dx.doi.org/10.1016/j.asr.2015.06.019>

Evidence for discrepancies in attitude modeling in MGEX solutions for low β angle.

Corrected clocks differences of different MGEX solutions (raw, c. Δ radial correction)

Glonass (doy 348/2016, $\beta = -0.9$ deg)
=> differences up to 0.8 nanosec*

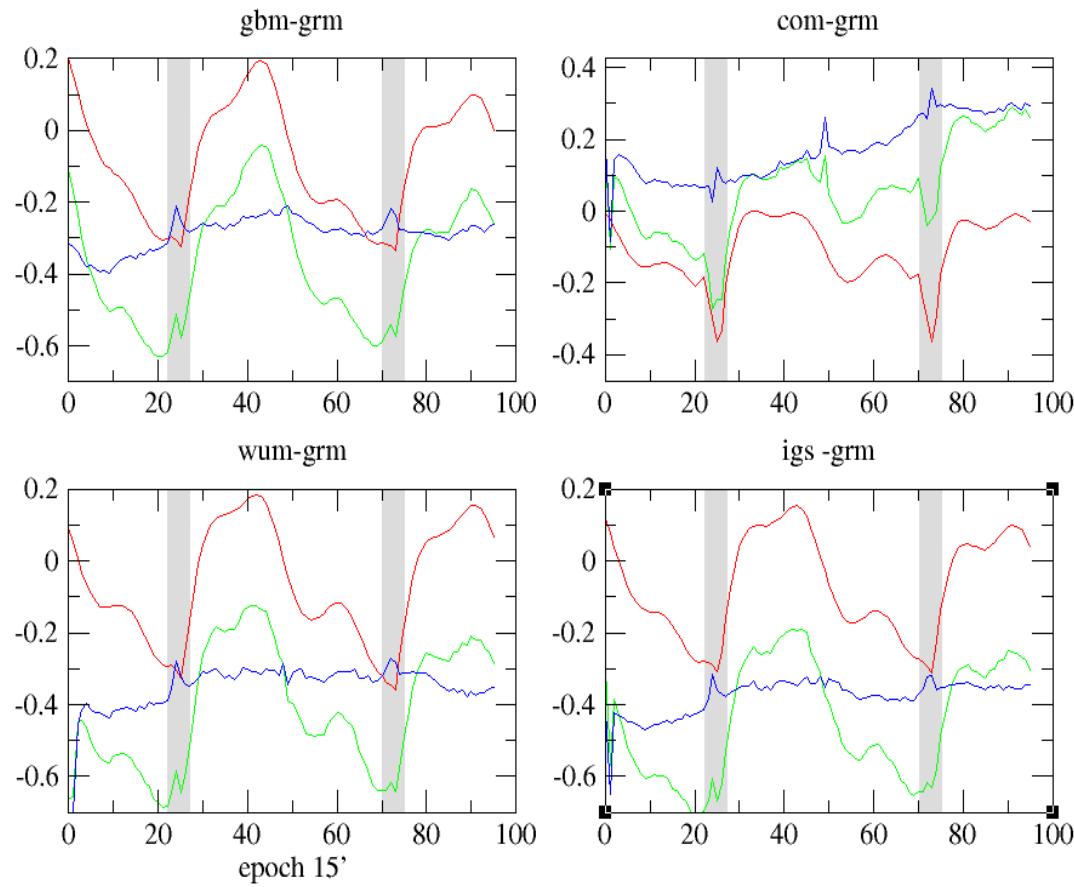


* 0.33 nanosec \sim 1 NL

**Corrected clocks
differences** of
different MGEX
solutions (raw,
 $c\Delta$ radial
correction)

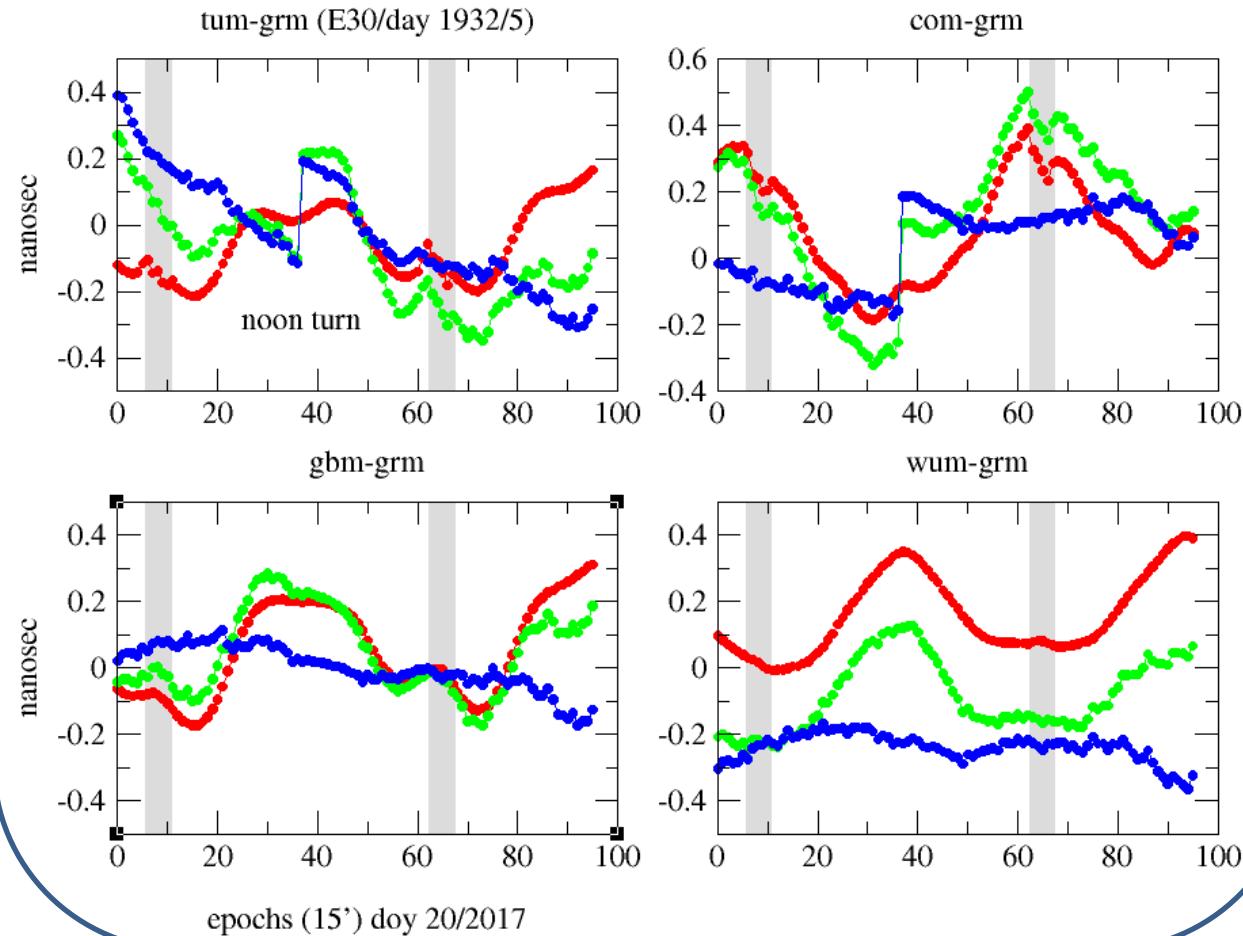
* 0.33 nanosec \sim 1 NL

GPS 30 IIF (doy 360/2016, $\beta = -1$ deg) =>
differences up to 0.2 nanosec*



**Corrected clocks
differences** of
different MGEX
solutions (raw,
 $c\Delta$ radial
correction)

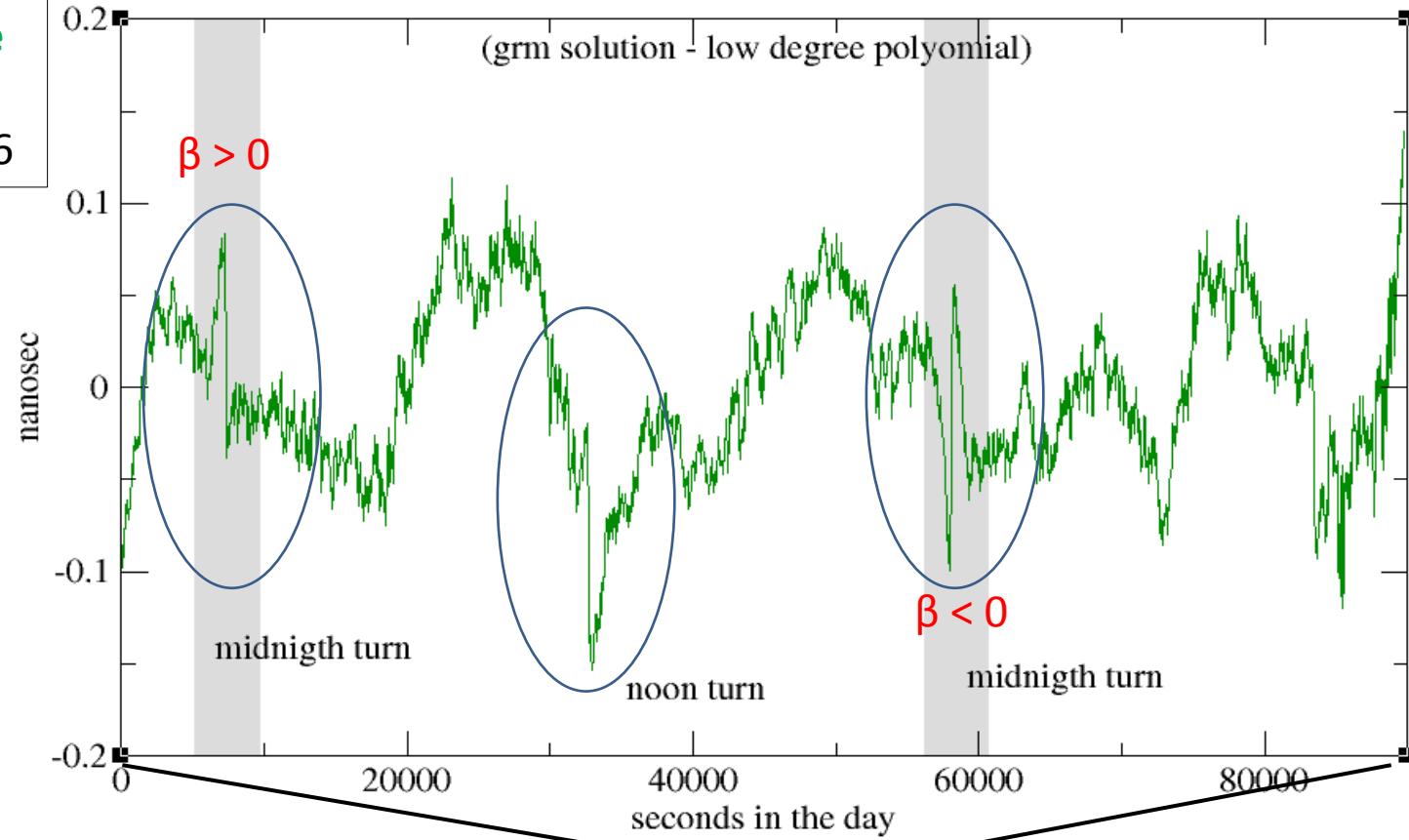
Galileo E30 FOC-6 (doy 020/2017, $\beta = -1$ deg)
=> differences up to 0.4 nanosec *



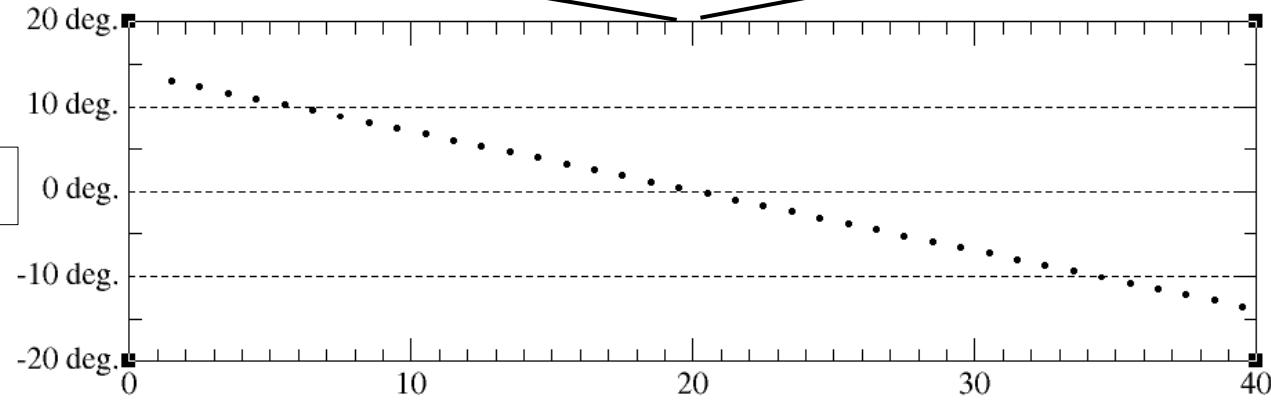
* 0.33 nanosec ~1 NL

For this particular case: there is agreement between solutions for midnight-turn but...this do not correspond to the reality as it can be seen directly on the clocks estimates (next slide...)

**Grm clock estimate
(minus low degree
polynomial) - FOC-6**



B-angle



Common attitude for all ACs ?

It seems impossible to have a common yaw/attitude modeling for all satellites/ACs (including eclipses seasons) for the following reasons:

- Some ACs have specific attitude yaw modeling linked to their strategy
- Even in the case ACs agree “on paper” new models are implemented at various time in the software's
- In cases of changes of attitude law models and/or for new satellites with new attitude law we should adopt a common switch (like for the ITRF14/igs14.atx switch for reference frame). Not easy to handle in practice...
- In any case, even if all IGS-ACs have the same attitude laws and did check their respective software's, this should ideally be done on the user side (implying many more different software's to be checked/modified).

Consequently users have a large probability to not use the same attitude modelling as the one used to compute the clocks. For IGS-like mixed products it is worse since nobody can even define the attitude law to be used.

How to make progress in that area?

A wrong attitude model could do partly the job if we have **coherent** clocks, orbits and attitude but for other reasons (force models, code-phase biases) it is preferable to use as realistic models as possible.

Re-activate the proposal to exchange the numerical values of attitude used:

- exchange/compare attitude values (for validation/comparison purpose)
- provide to users the attitude values used to generate the products (to be able to use with the best exactitude the eclipsing satellites)

How ? New orbits or clocks file? Separate attitude file? Exchange format (RINEX_clock_v3 / Orbex) ?

- RINEX clock v3 is not sufficient since it provides only yaw angle departure from nominal angle.
- Orbex more suitable since it provides the complete attitude quaternion (see <ftp.ngs.noaa.gov/pub/ORBEX/ORBEX008.pdf> (last version, May 2010 ?))
- attitude could be given relatively to terrestrial frame (to avoid J2000-TRF transformations for users)
- have to be provided at a sufficient rate (e.g 30'' as clocks) at least during eclipsing seasons...

Part 2

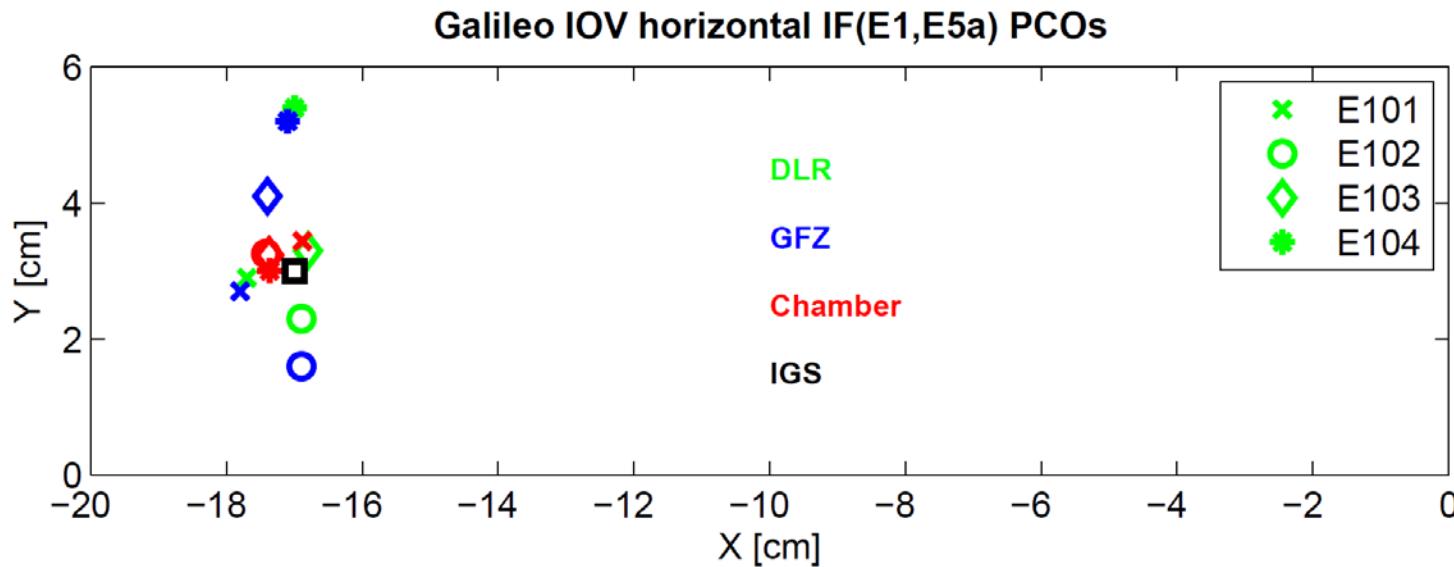
Antenna Models

- ESA/GSC provides
 - Center-of-mass (CoM) location
 - Antenna reference point (ARP)
 - Phase center offset (PCO) w.r.t. ARP (for each frequency)
 - Phase variations (PVs) (for each frequency)
- IGS needs
 - PCO w.r.t. CoM (i.e. $\text{PCO}_{\text{IGS}} = \text{ARP}_{\text{ESA}} - \text{CoM}_{\text{ESA}} + \text{PCO}_{\text{ESA}}$)
 - PV
- IGS has
 - PCOs of IOV and FOC for E1/E5a (GFZ/DLR campaign)

Erroneous COSPAR-IDs in IOV_NAVANT.atx

- 2011-???A/B for E103/4 instead of 2012-055A/B
- Correction requested via Help Desk of the European GNSS Service Center

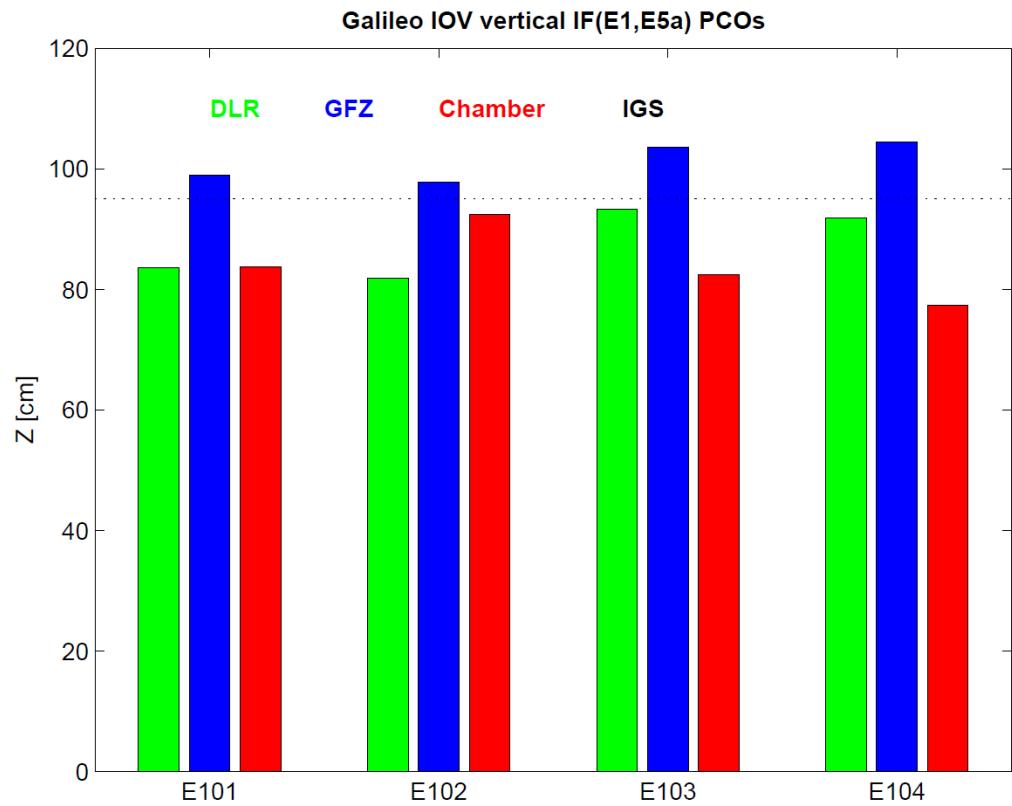
PCO Comparison – Horizontal



- Chamber measurements close to current IGS conventional value
- ± 0.5 cm / ± 2 cm scatter of observed X-/Y-component
- Good agreement within observational limits

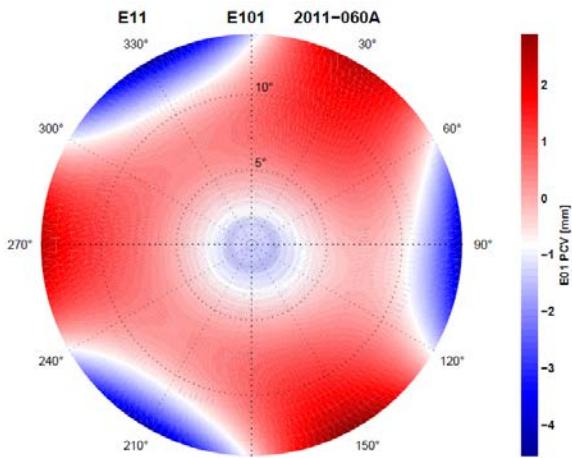
PCO Comparison – Vertical

- Systematic offset (~15 cm) of GFZ and DLR estimates (elev.-dep. weighting?)
- Differences of calibrated and estimated z-PCOs comparable to uncertainty of estimated values
- Use of estimated PCOs promises consistency of IOV and FOC PCOs
- Use of ESA calibrations offers access to single-frequency PCOs

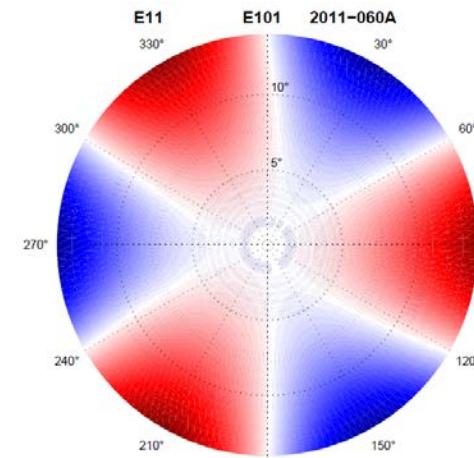


Phase Variations (IOV-1)

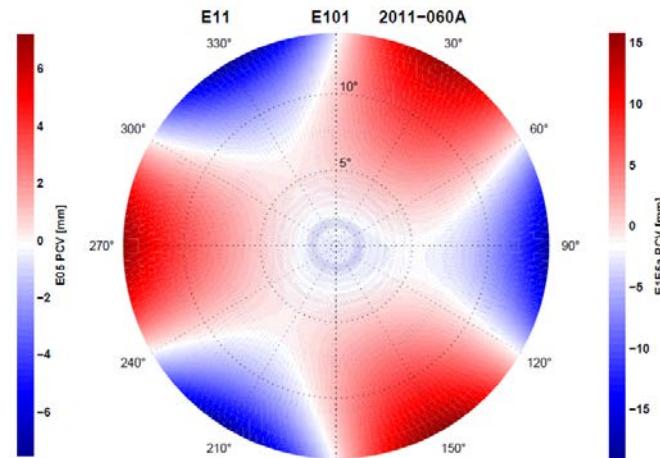
E1



E5a



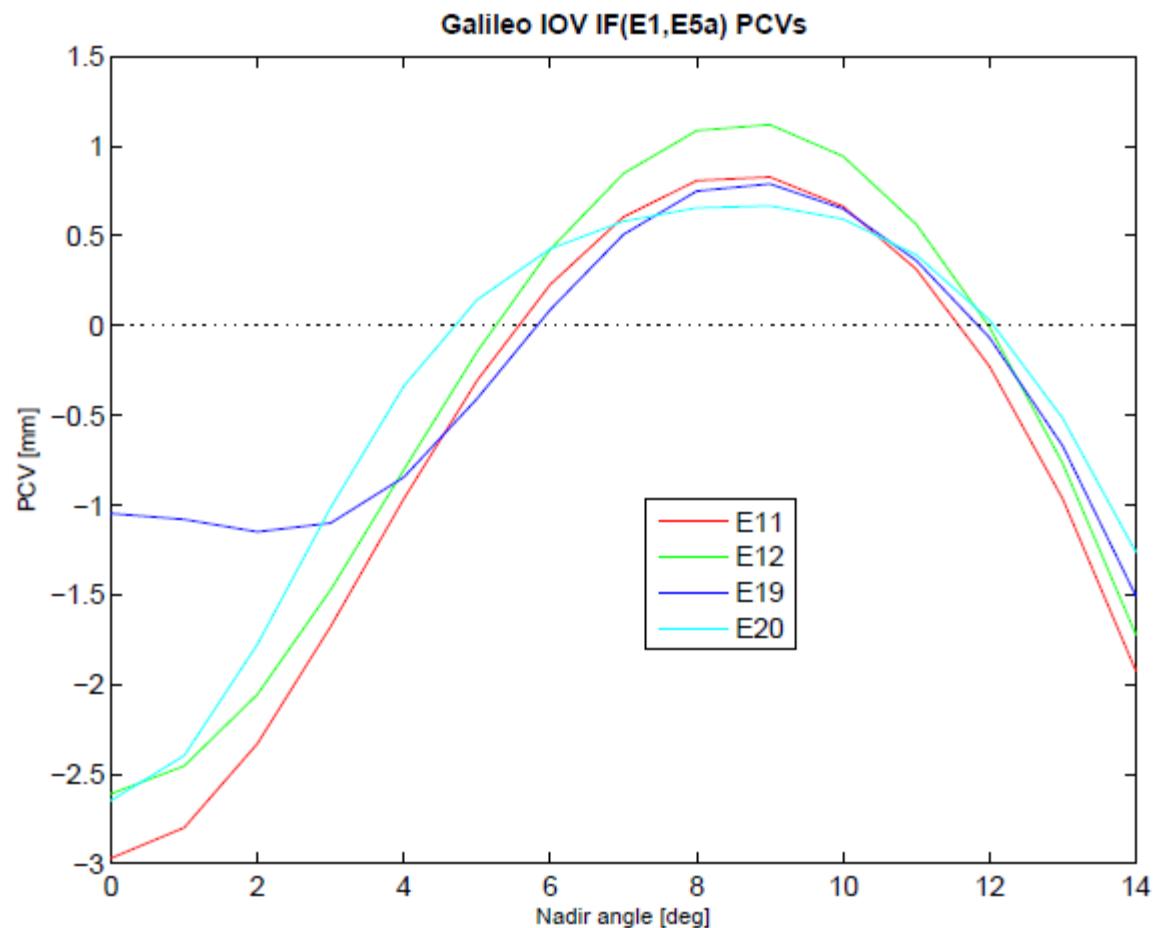
IF(E1,E5a)



- “Wind-mill” pattern, most pronounced on E5a/b/ab
- Up to ± 15 mm in ionosphere-free E1/E5a combination
- Fairly flat azimuth-averaged PCV (± 2 mm in E1/E5a)

Azimuth-Averaged Phase Variations

- -3 mm ... +1 mm in IF(E1,E5a)
- Similar for all IOV satellites except IOV-3



Adjustment of PCOs

- Factory calibrations not fully consistent with observed phase center for ionosphere-free combination
- Re-adjust PCOs to fit observations?
- n equations, $n+1$ unknowns

$$\Delta\text{PCO}_{E1/E5a} = \Delta\text{PCO}_{E1} - \frac{f_{E5a}^2}{f_{E1}^2 - f_{E5a}^2} (\Delta\text{PCO}_{E5a} - \Delta\text{PCO}_{E1})$$

$$\Delta\text{PCO}_{E1/E6} = \Delta\text{PCO}_{E1} - \frac{f_{E6}^2}{f_{E1}^2 - f_{E6}^2} (\Delta\text{PCO}_{E6} - \Delta\text{PCO}_{E1})$$

...

- Possible constraints:
 - Reference constraint $\Delta\text{PCO}_{E1} = 0$
 - Zero-mean constraint $\Delta\text{PCO}_{E1} + \Delta\text{PCO}_{E5a} + \dots = 0$
 - Equal shifts $\Delta\text{PCO}_{E1} = \Delta\text{PCO}_{E5a}$
 - ...
- How to adjust PCOs for unobserved frequencies?

Example PCO Adjustment

| | calib [mm] | obs [mm] | A [mm] | dA [mm] | B [mm] | dB [mm] | C [mm] | dC [mm] |
|--------|---------------|-------------|-----------|------------|-----------|------------|-----------|------------|
| E1 | 812 | | 812 | 0 | 844 | 32 | 925 | 113 |
| E5a | 792 | | 703 | -89 | 760 | -32 | 905 | 113 |
| E1/E5a | 837 | 950 | 950 | | 950 | | 950 | |
| E6 | 710 | | | | | | | |
| E1/E6a | 1009 | ? | | | | | | |

Correct

- E5a PCO by -89 mm (option A) or
 - E1 by +32 mm and E5a by -32 mm (option B) or
 - E1 and E5a by 113 mm (option C)
- to change E1/E5a PCO from 837 to 950 mm

Questions on IGS Antenna Model



- General
 - use ESA data for IOV *or* merge these calibrations with GFZ/DLR PCO estimates?
 - use per-frequency data (e.g. E1, E5a, ...) *or* ionosphere-free combination (like in GPS/GLO)
- PCO
 - use satellite-specific *or* block mean *or* block mean for X, Y plus individual Z ?
- PVs
 - use azimuth+elevation dependent (2-dim) *or*
 - only elevation dependent (1-dim) *or*
 - none?
- Proposal
 - Update current ANTEX data set; “ignore” GFZ/DLR PCO calibrations
 - Insert unabridged ESA data set (individual satellite, all frequencies, 2-dim PV) into next ANTEX release
Notes: need to add ARP-CoG to PCO; need to double-check orientation
 - Use new ANTEX in MGEX product generation

Part 3

Solar Radiation Pressure Models

- Galileo IOV
 - Surface areas and properties published by EU/ESA in Dec. 2016
 - <https://www.gsc-europa.eu/support-to-developers/galileo-iov-satellite-metadata>
 - Experience?
 - Issues?
- QZSS
 - New DLR box-wing model
 - New “ECOM-ON” frame for ECOM parameters estimation in orbit-normal mode
 - <http://dx.doi.org/10.1016/j.asr.2017.01.036>

- Areas and optical parameters for
 - 6 faces of “brick”-like (cuboid) box
 - Solar panels
 - Up to two constituents per surface
- Only +z, +x, -z-faces and solar panels (SP) need to be considered in nominal yaw-steering

Characteristic Accelerations

| Panel | $\alpha+\delta$ [nm/s ²] | ρ [nm/s ²] | Sum [nm/s ²] | DLR model [nm/s ²] | Notes |
|-------------|---|--------------------------------|-----------------------------|--------------------------------------|--|
| +z | 17.8 | 1.8 | 19.6 | 19.5 | |
| -z | 19.5 | 0.0 | 19.5 | 19.5 | |
| +x | 7.7 | 0.9 | 8.6 | 9.5 | |
| zx | 13.2 | 0.9 | 14.1 | 14.5 | “Cubicness” |
| Δzx | 5.5 | 0.0 | 5.5 | 5.0 | “Stretchedness” |
| Δzx | -0.9 | +0.9 | 0.0 | 0.0 | |
| SP | | | 74.5 | 87.0 | No immediate (or symmetric) reemission of absorbed radiation |
| SP* | | | 87.2 | 87.0 | With $\alpha=0.75$, $\delta=0.04$, $\rho=0.21$ |

Montenbruck O., Steigenberger P., Hugentobler U.; *Enhanced Solar Radiation Pressure Modeling for Galileo Satellites*; Journal of Geodesy 89(3):283-297 (2015). DOI 10.1007/s00190-014-0774-0

- Box contribution
 - Assume spontaneous reemission of absorbed radiation (only sum of $\alpha+\delta$ matters)
 - Good overall match with flight calibrated DLR cuboid model
 - Benefit of explicit modeling of specular reflection unclear
 - Modeling of y -contribution of interest for non-nominal yaw-steering
- Galileo IOV Solar panel parameters
 - “Standard” model does not account for reemission of absorbed radiation (=symmetric emission from front and back of panel)
 - Can only be used in combination with additional model for (asymmetric) thermal reemission (but no temperature data provided) or (more simply) by modified specular reflectivity

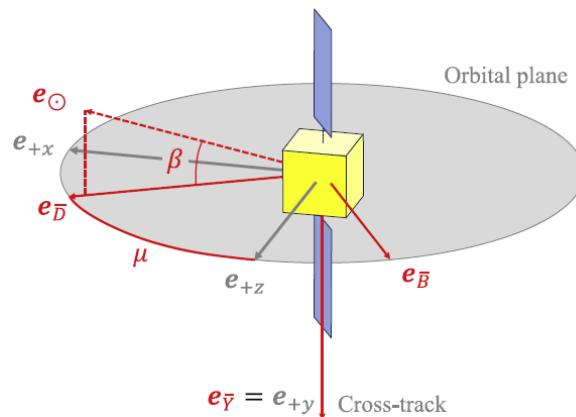
Discussion

- Galileo IOV
 - Which ACs can (plan to) make use of BW model?
 - How to best treat solar panels?
 - Need for ECOM1 on top of a priori BW model?
 - Improvement compared to current modeling?
 - Benefit (and applicability) for non-nominal attitudes?
 - Only short phase (~1h) and small incidence angles
 - QZSS analysis suggests “anomalous” y -acceleration outside the nominal yaw-steering

QZS-1 SRP Model

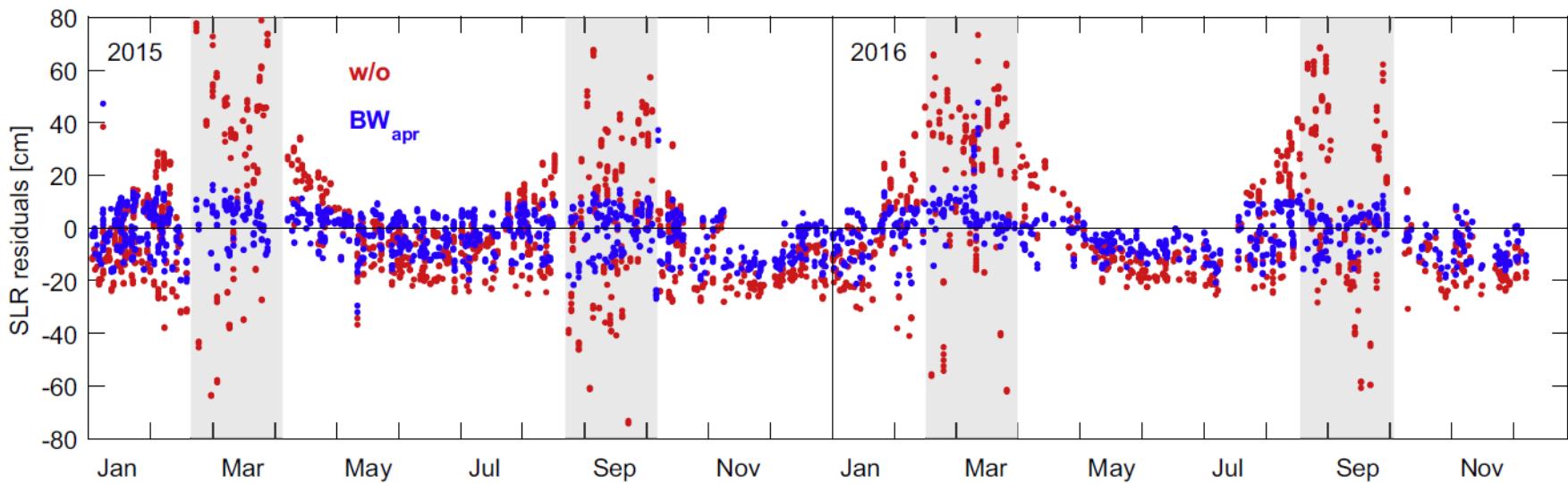
- Surface areas and adjusted “characteristic accelerations” for all six body faces plus solar panels
- For use with complementary ECOM-1
- Dedicated ECOM-ON frame for orbit-normal mode

| Parameter | Value [nm/s ²] | Parameter | Value [nm/s ²] |
|--------------------------------|----------------------------|-------------------------|----------------------------|
| $a_{zx}^{\alpha\delta}$ | 20.0 | $a_{+z}^{\alpha\delta}$ | 14.0 |
| a_{zx}^{ρ} | 0.0 | a_{+z}^{ρ} | 0.0 |
| $\Delta a_{zx}^{\alpha\delta}$ | -7.0 | $a_{-z}^{\alpha\delta}$ | 12.0 |
| Δa_{zx}^{ρ} | 0.0 | a_{-z}^{ρ} | 0.0 |
| $\Delta a_z^{\alpha\delta}$ | 0.0 | $a_{+x}^{\alpha\delta}$ | 27.0 |
| Δa_z^{ρ} | 0.0 | a_{+x}^{ρ} | 0.0 |
| $\Delta a_x^{\alpha\delta}$ | 0.0 | $a_{-x}^{\alpha\delta}$ | 27.0 |
| Δa_x^{ρ} | 0.0 | a_{-x}^{ρ} | 0.0 |
| $a_y^{\alpha\delta}$ | 7.0 | $a_{+y}^{\alpha\delta}$ | 7.0 |
| a_y^{ρ} | 15.0 | a_{+y}^{ρ} | 15.0 |
| $\Delta a_y^{\alpha\delta}$ | 0.0 | $a_{-y}^{\alpha\delta}$ | 7.0 |
| Δa_y^{ρ} | 0.0 | a_{-y}^{ρ} | 15.0 |
| $a_{sp}^{\alpha\delta}$ | 70.5 | | |
| a_{sp}^{δ} | 0.0 | | |
| a_{sp}^{ρ} | 21.0 | | |



QZS-1 SRP Model – SLR Validation

| Attitude | No box-wing mean $\pm \sigma$ [cm] | With box-wing mean $\pm \sigma$ [cm] |
|----------|---------------------------------------|---|
| YS | -5.4 ± 14.0 | -2.9 ± 8.0 |
| ON | 14.4 ± 33.3 | $+2.1 \pm 8.3$ |
| all | -0.5 ± 22.2 | -1.6 ± 8.4 |



Part 4

SINEX Satellite Metadata Format

Background

- Satellite metadata are vital for accurate modeling of GNSS data
 - Unique identifiers: SVN, COSPAR ID, Satellite Catalog Number (“NORAD ID”)
 - PRN/SVN mapping
 - Satellite mass
 - Center of mass
 - Eccentricities of “devices”: transmit antennas, laser retroreflector arrays, ...
- ANTEX format includes satellite metadata that is not related to the antenna
 - PRN/SVN mapping → highly redundant antenna records
- **SATELLITE/ID** block already available in SINEX format; requires only minor upgrades
 - Add constellation letters in PRN
 - Add Satellite Catalog Number
 - Transition from 2-digit year to 4-digit year
 - Replace *antenna* name by *satellite block* name

Option A: Satellite ID including PRN/SVN



+SATELLITE/ID

| * SVN | PRN | COSPAR ID | SATCAT | VALID_FROM... | TO | BLOCK | |
|-------|-----|-----------|--------|---------------|----------------|----------------|------------|
| C017 | C15 | 2016-021A | 41434 | P | 2016:089:00000 | 2016:285:18000 | BEIDOU-2I |
| C017 | C13 | 2016-021A | 41434 | P | 2016:285:27000 | 0000:000:00000 | BEIDOU-2I |
| E101 | E11 | 2011-060A | 37846 | P | 2011:294:00000 | 0000:000:00000 | GALILEO-1 |
| E201 | E18 | 2014-050A | 40128 | P | 2014:234:00000 | 0000:000:00000 | GALILEO-2 |
| G023 | G23 | 1990-103A | 20959 | P | 1990:330:00000 | 2004:053:86399 | GPS-IIA |
| G023 | G32 | 1990-103A | 20959 | P | 2006:336:00000 | 2016:025:86399 | GPS-IIA |
| J001 | J01 | 2010-045A | 37158 | P | 2010:254:00000 | 0000:000:00000 | QZS-1 |
| R802 | R27 | 2014-075A | 40315 | P | 2014:334:00000 | 2016:026:86399 | GLONASS-K1 |
| R802 | R09 | 2014-075A | 40315 | P | 2016:047:00000 | 0000:000:00000 | GLONASS-K1 |
| R802 | R17 | 2014-075A | 40315 | P | 2016:027:00000 | 2016:046:86399 | GLONASS-K1 |
| . | . | . | . | . | . | . | |
| . | . | . | . | . | . | . | |
| . | . | . | . | . | . | . | |

-SATELLITE/ID

Option B: Separate PRN Block



+SATELLITE/ID

| * | SVN | COSPAR ID | SATCAT BLOCK | |
|------|-----------|-----------|--------------|--|
| C017 | 2016-021A | 41434 | BEIDOU-2I | |
| E101 | 2011-060A | 37846 | GALILEO-1 | |
| E201 | 2014-050A | 40128 | GALILEO-2 | |
| G023 | 1990-103A | 20959 | GPS-IIA | |
| J001 | 2010-045A | 37158 | QZS-1 | |
| R802 | 2014-075A | 40315 | GLONASS-K1 | |

-SATELLITE/ID

SATELLITE/PRN block
contains only PRN/SVN
mapping

SATELLITE/ID block only
contains unique information that
does not require a validity interval

+SATELLITE/PRN

| * | SVN | PRN | T | VALID_FROM...TO |
|------|-----|-----|----------------|-----------------|
| C017 | C15 | P | 2016:089:00000 | 2016:285:18000 |
| C017 | C13 | P | 2016:285:27000 | 0000:000:00000 |
| E101 | E11 | P | 2011:294:00000 | 0000:000:00000 |
| E201 | E18 | P | 2014:234:00000 | 0000:000:00000 |
| G023 | G23 | P | 1990:330:00000 | 2004:053:86399 |
| G023 | G32 | P | 2006:336:00000 | 2016:025:86399 |
| J001 | J01 | P | 2010:254:00000 | 0000:000:00000 |
| R802 | R27 | P | 2014:334:00000 | 2016:026:86399 |
| R802 | R09 | P | 2016:047:00000 | 0000:000:00000 |
| R802 | R17 | P | 2016:027:00000 | 2016:046:86399 |

-SATELLITE/PRN

Satellite Center of Mass

- Coordinates of spacecraft center of mass relative to agreed-upon origin (e.g., mechanical reference system defined by manufacturer)
 - Values refer to IGS conventions for orientation of spacecraft body axes¹⁾
 - Use zero value if no CoM location is available.
- Example for Galileo IOV-1 (E101) based on data from ILRS
 - Data sets with identical CoM values have been merged

+SATELLITE/COM

| * SVN | VALID_FROM... | TO | X_[m] | Y_[m] | Z_[m] |
|-------|----------------|----------------|----------|----------|---------|
| E101 | 2011:294:00000 | 2012:277:50560 | -1.20590 | -0.62890 | 0.55340 |
| E101 | 2012:277:50561 | 2014:324:63246 | -1.20587 | -0.62895 | 0.55343 |
| E101 | 2014:324:63247 | 0000:000:00000 | -1.20584 | -0.62897 | 0.55344 |

-SATELLITE/COM

¹⁾ O. Montenbruck, R. Schmid, F. Mercier, P. Steigenberger, C. Noll, R. Fatkulin, S. Kogure, A. S. Ganeshan (2015) "GNSS Satellite Geometry and Attitude Models", Advances in Space Research 56(6), DOI [10.1016/j.asr.2015.06.019](https://doi.org/10.1016/j.asr.2015.06.019)

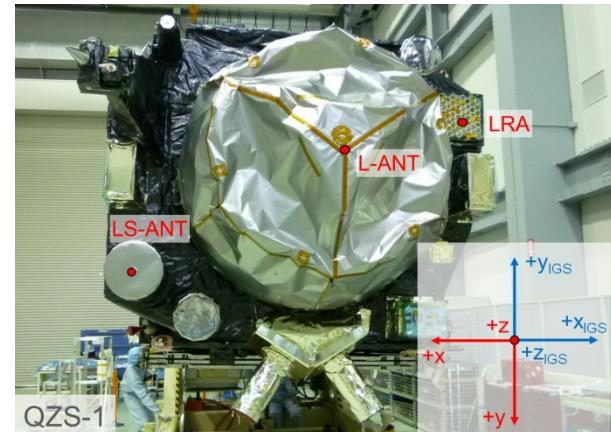
Satellite Mass

- Example for Galileo based on data from ILRS
 - Records with identical mass have been merged
 - Mass increase of +4 g for last record of E201 (bookkeeping uncertainty)

| +SATELLITE/MASS | | |
|-----------------|-------------------------------|-----------|
| * | SVN VALID_FROM...TO | MASS_[KG] |
| E101 | 2011:294:00000 2012:277:50560 | 698.815 |
| E102 | 2011:294:00000 0000:000:00000 | 695.328 |
| E103 | 2012:286:00000 0000:000:00000 | 697.632 |
| E104 | 2012:286:00000 0000:000:00000 | 695.652 |
| E201 | 2014:234:00000 2014:324:63246 | 661.030 |
| E201 | 2014:324:63247 2015:065:53958 | 660.973 |
| E201 | 2015:065:53959 0000:000:00000 | 660.977 |
| -SATELLITE/MASS | | |

Satellite Eccentricity

- Eccentricities for various devices relative to spacecraft body system
 - IGS axes conventions, same origin as CoM data
 - Device name matches ANTEX code
 - Antenna reference points for different GNSS transmit antennas
 - Laser retroreflector array (LRA) offset
- Example for QZS-1 with two different GNSS transmit antennas and a LRA
 - ARP_{Z,L-ANT} arbitrarily set to a rounded value of +4.8 m
 - Observation code T: P – GNSS; L – SLR


+SATELLITE/ECCENTRICITY

| * SVN DEVICE | T | X_[m] | Y_[m] | Z_[m] |
|---------------------|----------|--------------|--------------|--------------|
| J001 QZS-1_L-ANT | P | 0.00000 | 0.00000 | 4.80000 |
| J001 QZS-1_LS-ANT | P | -1.15000 | -0.70000 | 4.83500 |
| J001 QZS-1_LRA | L | 1.15000 | 0.55000 | 4.45030 |

-SATELLITE/ECCENTRICITY

Benefits

- Centralized interface for GNSS satellite metadata
 - Avoids redundancy
 - Facilitates maintenance of satellite database in PPP/POD S/W
- Enables “clean-up” of ANTEX antenna model
- Extendible to further information, e.g.
 - **SATELLITE/BOX_WING**
 - **SATELLITE/TX_POWER**
 - **SATELLITE/CLOCK**
- Extendible to LEO satellite data

Points for Discussion

- Length and choice of satellite (block) names
- Length and choice of device names
- 2-digit vs. 4-digit year
- Field length and width for coordinates
- GLONASS frequency channel
- Extensions for VLBI/SLR/DORIS/LEO?
 - These satellites have no SVN. Use COSPAR ID as unique identifier in **SATELLITE/COM**, **SATELLITE/MASS**, **SATELLITE/ECCENTRICITY**?
 - Add **SATELLITE/ALIGNMENT** for orientation of devices on LEO satellites

Implications for ANTEX++

- Remove PRN information, retain only SVN & COSPAR ID
- Provide PCO/PV information only *once* per SVN
- Remove obsolete validity interval
- Refer PCO to ARP rather than CoM; change label

| | | | | |
|-----------------|---------------------|---------------|---------------|---|
| BLOCK IIA | G01 | G032 | 1992-079A | START OF ANTENNA |
| | COD/EMR/ESA/GFZ/MIT | 0 | 25-MAR-11 | TYPE / SERIAL NO |
| 0.0 | | | | METH / BY / # / DATE |
| 0.0 | 17.0 | 1.0 | | DAZI |
| 1 | | | | ZEN1 / ZEN2 / DZEN |
| 1992 | 11 | 22 | 0 | # OF FREQUENCIES |
| 2008 | 10 | 16 | 59 | 0.0000000 |
| | | | | VALID FROM |
| | | | | VALID UNTIL |
| IGS08_1930 | | | | SINEX CODE |
| G01 | | | | START OF FREQUENCY |
| 279.00 | 0.00 | 2380.80 | | X O /TY / Z A S T / UP |
| NOAZI | -0.80 | -0.90 | -0.90 | 0.80 ... |
| G01 | | | | END OF FREQUENCY |
| END OF ANTENNA | | | | |

GLONASS Frequency Channel^{*)}



+SATELLITE/FREQUENCY_CHANNEL

| * SVN | VALID_FROM | VALID_UNTIL | CHN |
|-------|----------------|----------------|-----|
| R701 | 2003:344:00000 | 2009:256:86399 | 1 |
| R701 | 2009:257:00000 | 2010:117:86399 | -4 |
| R711 | 2001:335:00000 | 2006:078:86399 | 2 |
| R711 | 2006:079:00000 | 2009:347:86399 | 7 |
| R712 | 2004:361:00000 | 2007:036:86399 | 4 |
| R712 | 2007:037:00000 | 2011:348:86399 | 5 |
| R712 | 2012:292:00000 | 2012:304:86399 | -6 |
| . | . | . | . |
| . | . | . | . |
| R854 | 2014:101:00000 | 0000:000:00000 | -3 |
| R855 | 2014:214:00000 | 0000:000:00000 | 4 |

-SATELLITE/FREQUENCY_CHANNEL

-SATELLITE/ID

^{*)} Thanks to Simon Banville!

Part 5

Product Naming Conventions

New File Naming Convention

AAAVPPPTT_YYYDDDHMM_LEN_SMP_CN_T.FMT[.?_{*}]

GFZ0MGXRAP_20160010000_01D_05M_ORB.SP3.gz

| | | |
|-------|------|--|
| 01-03 | AAA | 3-char AC name (e.g. GFZ) |
| 04 | V | 1-char version/solution identifier (nominally 0) |
| 05-07 | PPP | 3-char campaign/project specification (e.g.: "MGX") |
| 08-10 | TTT | 3-char product type specification (here: RAP for "rapid", and FIN for "final") |
| 11 | | 1-char separator (underline) |
| 12-15 | YYYY | 4-digit year of start epoch |
| 16-18 | DDD | 3-digit day-of-year of start epoch |
| 10-20 | HH | 2-digit hour of start epoch (her: 00) |
| 21-22 | MM | 2-digit minute of start epoch (here: 00) |
| 23 | | 1-char separator (underline) |
| 24-26 | LEN | 2-digits+1-char intended (nominal) product period (e.g. 01D for 1-day) |
| 27 | | 1-char separator (underline) |
| 28-30 | SMP | 2-digits+1-char sampling interval (e.g 15M for 15-min; 000 if not-applicable) |
| 31 | | 1-char separator (underline) |
| 32-34 | CNT | 3-char content type (e.g.: „ORB“) |
| 35 | . | 1-char separator |
| 36-38 | FMT | 3-char format extension (e.g.: "SP3") |

New File Naming Convention (cntd.)



| Field | Tags | Description |
|------------------|--|---|
| Analysis center | IGS, COD,EMR,ESA,GFZ,GRG,JPL/MIT,NGS, WUH, ... | IGS ACC (for combined products) or individual AC designator |
| Campaign/project | OPS | Operational IGS products |
| | RP1, RP2, ... | Reprocessing campaigns |
| | MGX | Multi-GNSS pilot project (MGEX) |
| | TGA | Tide Gauge Benchmark Monitoring (TIGA) |
| Product type | FIN | Final |
| | RAP | Rapid |
| | ULT | Ultra-rapid |
| | RTM | Real time streams written to file |
| Contents type | ORB (or EPH?) | Orbit+(clock) ephemeris (typically in SP3 format) |
| | CLK | Satellite/receiver clocks |
| | EOP | Earth orientation parameters |
| | TRP | Troposphere related product |
| | ION | Ionosphere product |
| | SOL | Solutions (typically in SINEX format) |
| | CRD | Station coordinates/velocities (typically in SINEX format) |
| | BIA | Biases |

Conclusions

Conclusions (Eclipse Models)



- To be supplied at/after meeting

Conclusions (Antenna Models)



- To be supplied at/after meeting

Conclusions (SRP Models)



- To be supplied at/after meeting

Conclusions (Sat Metadata Format)



- To be supplied at/after meeting

Conclusions (Product File Names)



- To be supplied at/after meeting