# COPERNICUS POD SERVICE
## VALIDATION OF COPERNICUS SENTINEL-3 ORBITS

S3VT 2019, 7 – 9 May; ESRIN, Italy

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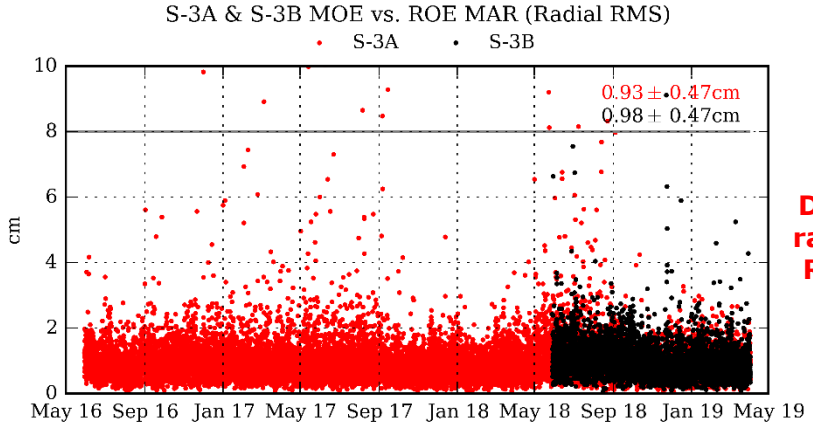
# OUTLINE

- The accuracy of operational Sentinel-3 POD orbital products
  - NRT, STC, NTC
- The combined orbit solution
  - Procedure
  - Comparison results
- New Standards
  - IAR
  - Gravity field
- Conclusions

# CPOD SERVICE – VALIDATION OF COPERNICUS SENTINEL-3 ORBITS

# THE ACCURACY OF OPERATIONAL SENTINEL-3 POD ORBITAL PRODUCTS

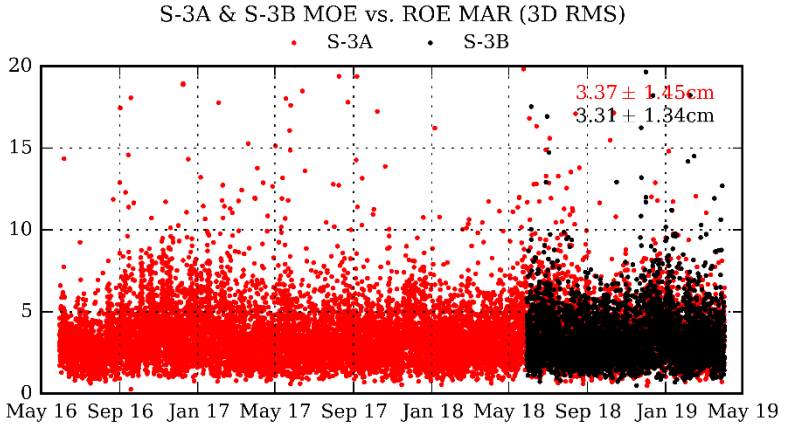
# S-3 MOEORB vs. ROE@MAR / DORIS_NAV

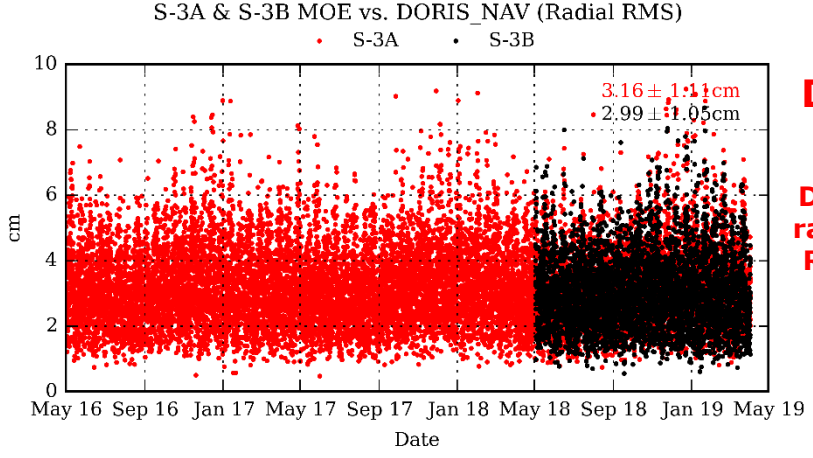



**ROE@MAR**

**Daily radial RMS**

**Daily 3D RMS**

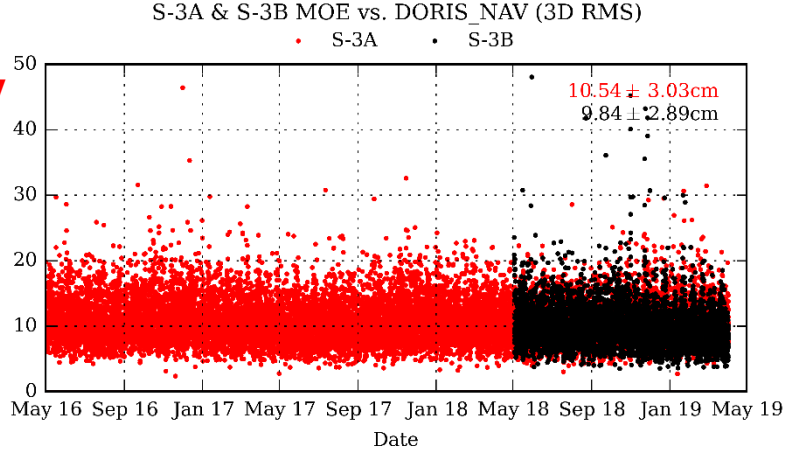


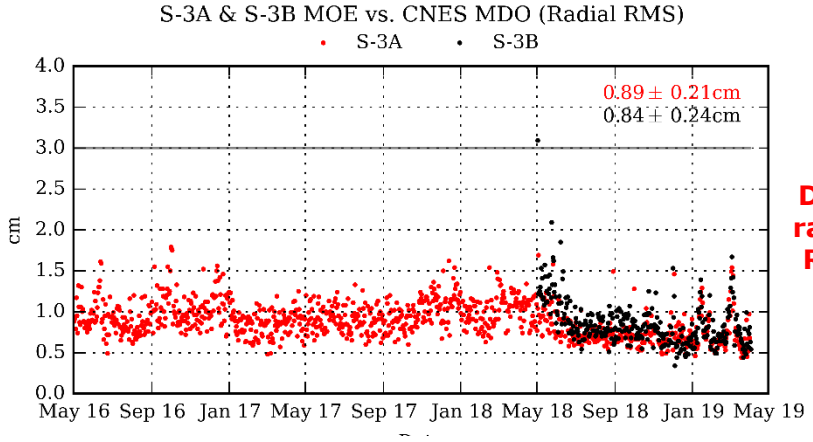

**DORIS_NAV**

**Daily radial RMS**

**Daily 3D RMS**

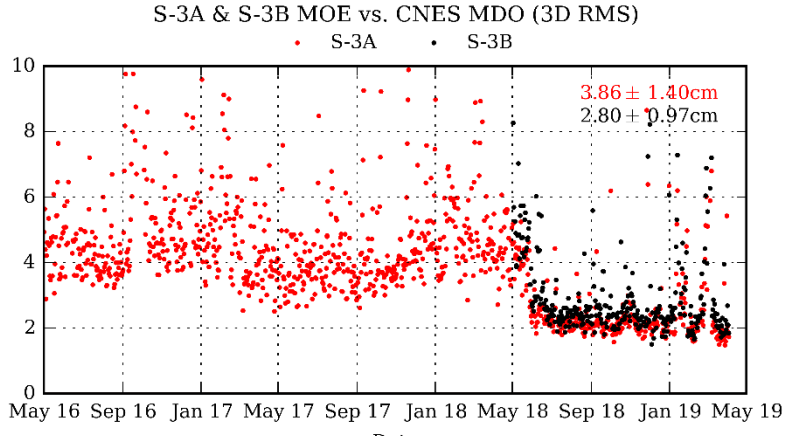


# S-3 CPOD vs. CNES – STC & NTC

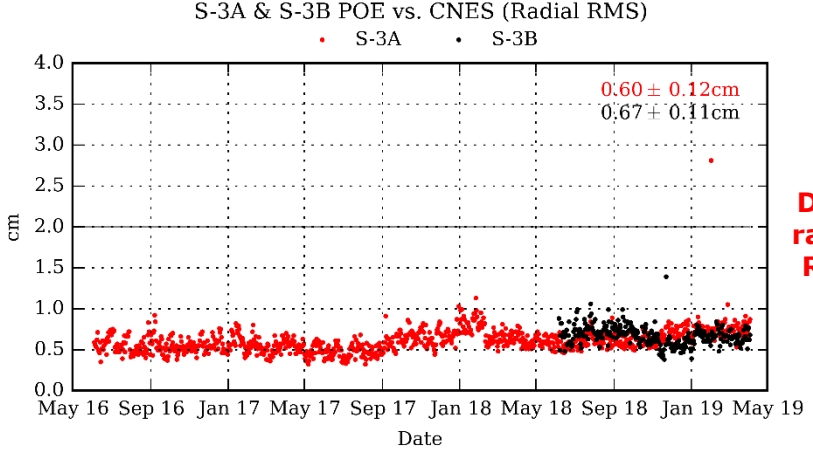



**STC**

**Daily radial RMS**

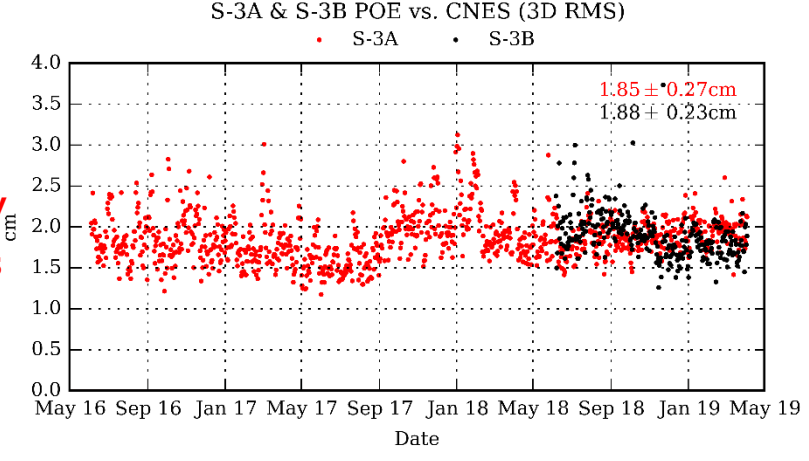



**Daily 3D RMS**




**NTC**

**Daily radial RMS**




**Daily 3D RMS**

# CPOD SERVICE – VALIDATION OF COPERNICUS SENTINEL-3 ORBITS

# THE COMBINED ORBIT SOLUTION

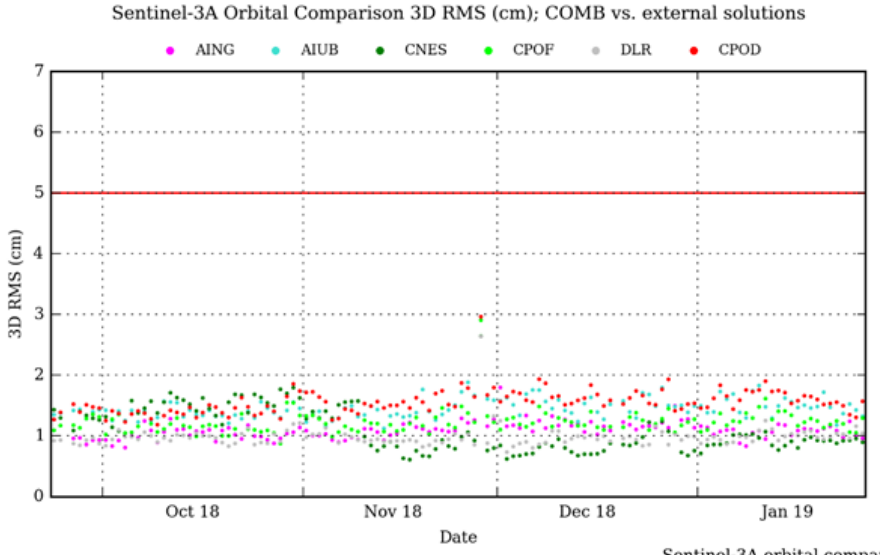
# SENTINEL-3 COMBINED SOLUTION

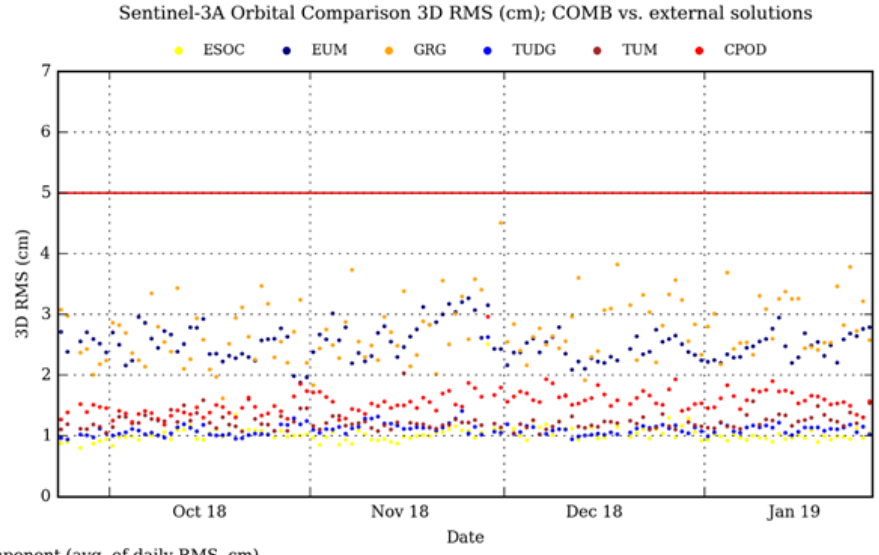
- The Copernicus POD Service generates a combined orbit every four months, in the frame of the Regular Service Review.
- The combined orbit is computed as a weighted mean of several independent orbits.
- The independent orbits are summarized in the following table:

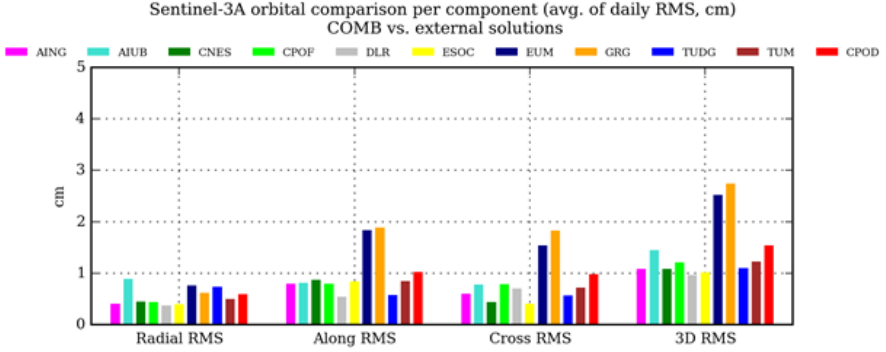
| | AIUB | CNES | CPOD | DLR | ESOC | EUM | GRG | TUD | TUM |
|---|---|---|---|---|---|---|---|---|---|
| SW | BERNESE | **Zoom** | **NAPEOS** | Ghost | NAPEOS | NAPEOS | GINS / DYNAMO | GIPSY | BERNESE |
| DATA | GPS | **GPS+DORIS** | **GPS** | GPS | GPS | GPS | DORIS | GPS | GPS |
| Approach | Kinematic / Reduced Dynamic | **Reduced Dynamic** | **Reduced Dynamic** | Reduced Dynamic | Reduced Dynamic | Reduced Dynamic | Reduced Dynamic | Reduced Dynamic | Reduced Dynamic |

- Procedure:
  1. Firstly a unweighted mean orbit is computed
  2. The differences of each individual orbit vs. the unweighted mean is computed. A daily weight per orbit is computed.
  3. A weighted mean orbit is finally computed.
- Note: The weights are per solution and day. The same weight is used for all the state-vectors in a single day.

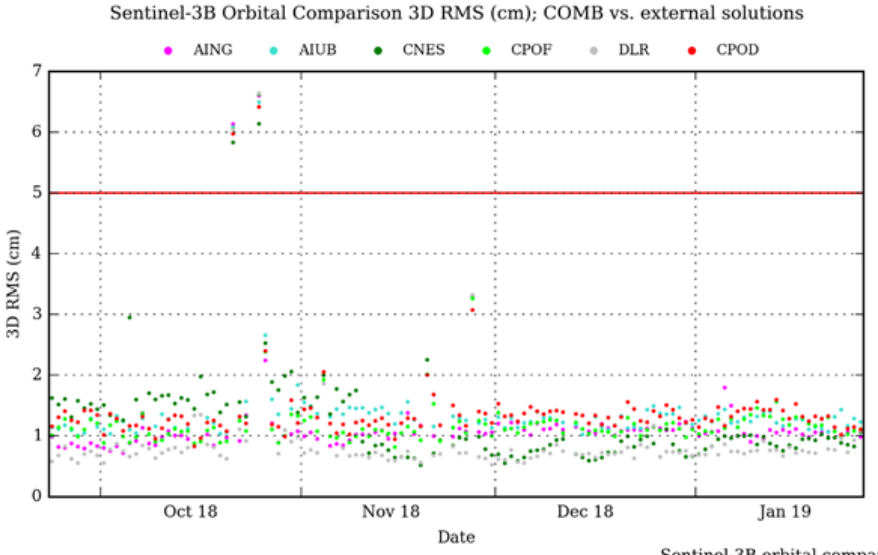
# SENTINEL-3A COMBINED SOLUTION

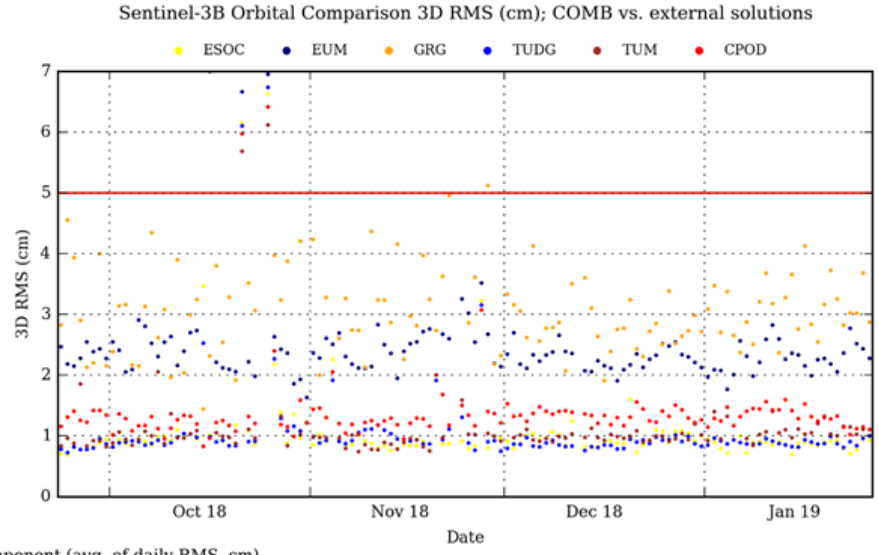


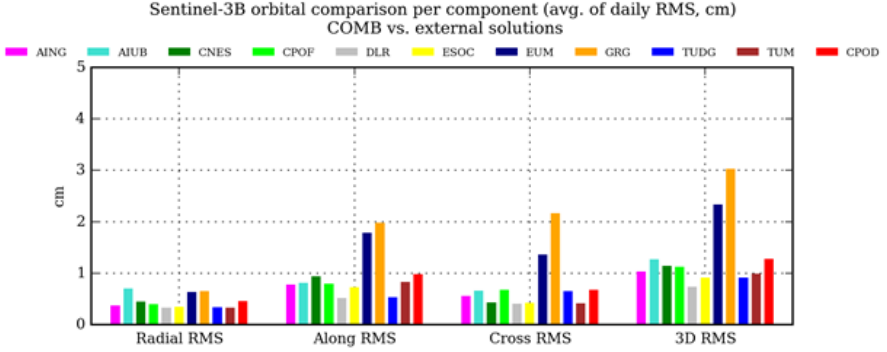



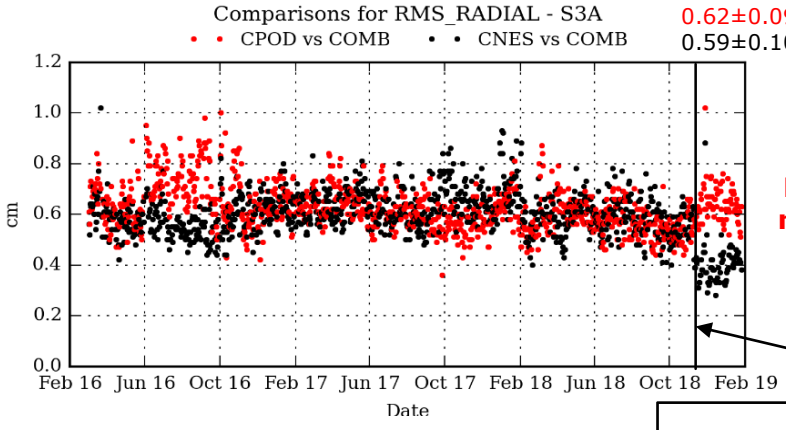
# SENTINEL-3B COMBINED SOLUTION



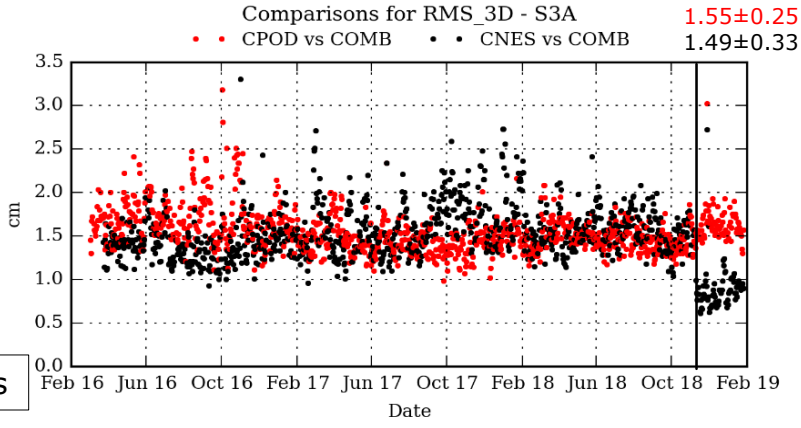
# S3 CPOD/CNES vs COMB



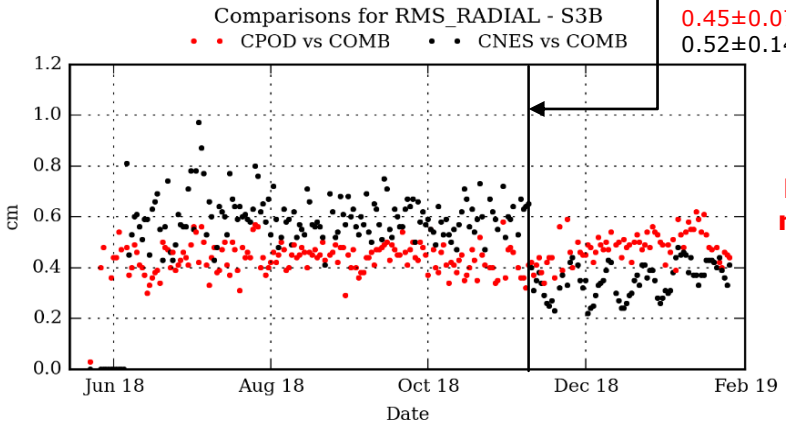

S3A

Daily radial RMS

Daily 3D RMS



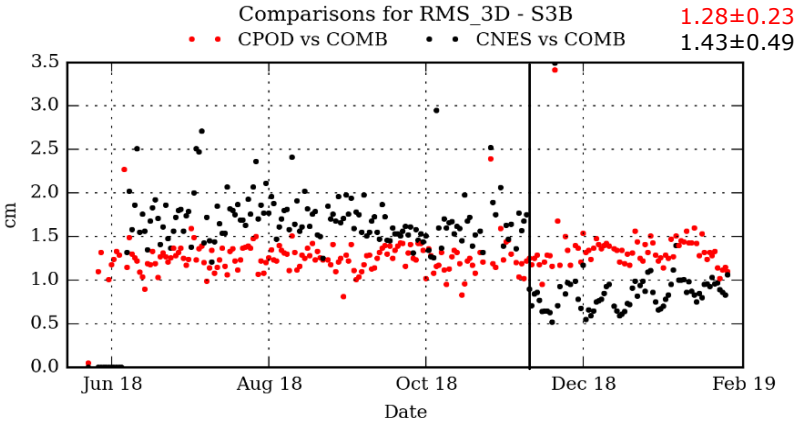

New Standards




S3B

Daily radial RMS

Daily 3D RMS



# CPOD SERVICE – VALIDATION OF COPERNICUS SENTINEL-3 ORBITS

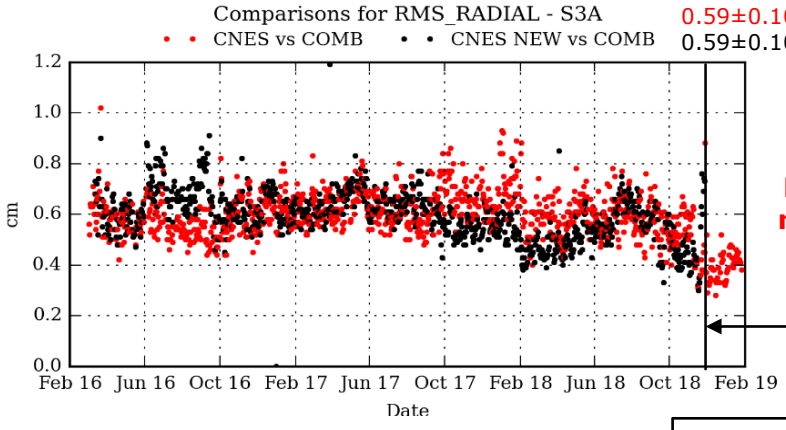
# NEW STANDARDS

# NEW STANDARDS

- CNES is currently generating its STC/NTC products based on a set of new standards.

| | CNES POE-E | CNES POE-F | CPOD |
|---|---|---|---|
| Gravity Field | EIGEN-GRGS.RL03-v2.MEAN-FIELD | EIGEN-GRGS.RL04-v1.MEAN-FIELD | EIGEN.GRGS.RL03.v2 |
| Ocean tides | FES2012 | FES2014 | EOT11a |
| Oceanic/atmospheric gravity | 6hr NCEP pressure fields (70x70) + tides from Biancale-Bode model | 3hr dealiasing products from GFZ AOD1B RL06 | AGRA |
| Atmospheric density model | MSIS86 | MSIS-00 | MSIS-90 |
| Terrestrial Reference Frame | ITRF2008 | ITRF2014 | ITRF2014 |
| Estimated measurement parameters | GPS: floating ambiguity per pass, receiver clock adjusted per epoch | GPS: fixed ambiguity only for NTC orbits and when possible per pass, receiver clock adjusted per epoch | GPS: floating ambiguity per pass, receiver clock adjusted per epoch |

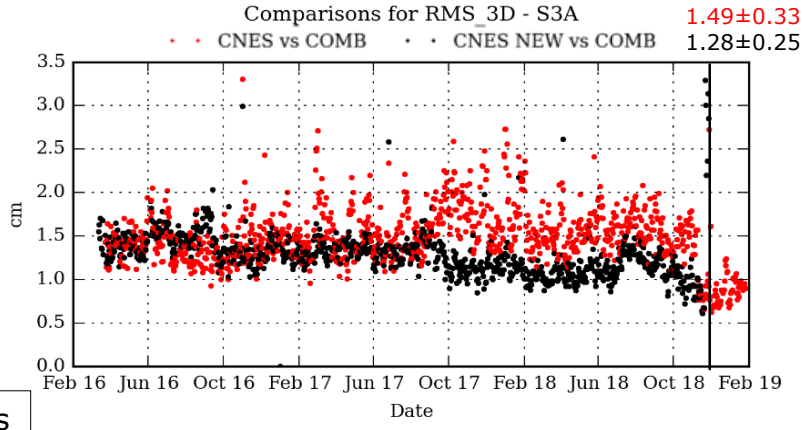
# COMPARISONS – CNES vs COMB



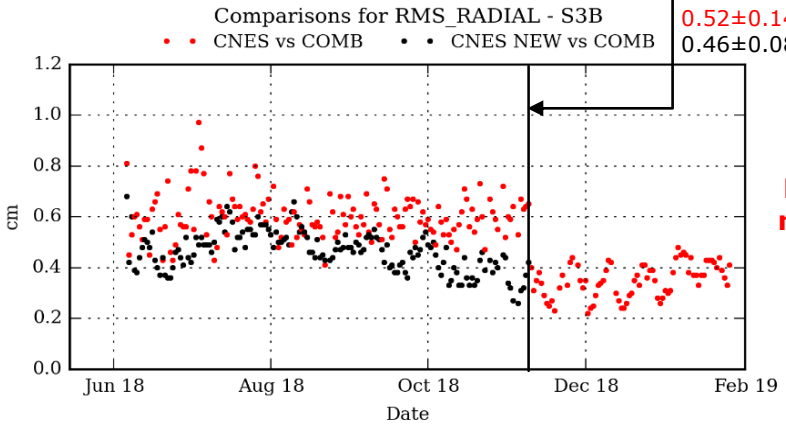

S3A

Daily radial RMS

Daily 3D RMS



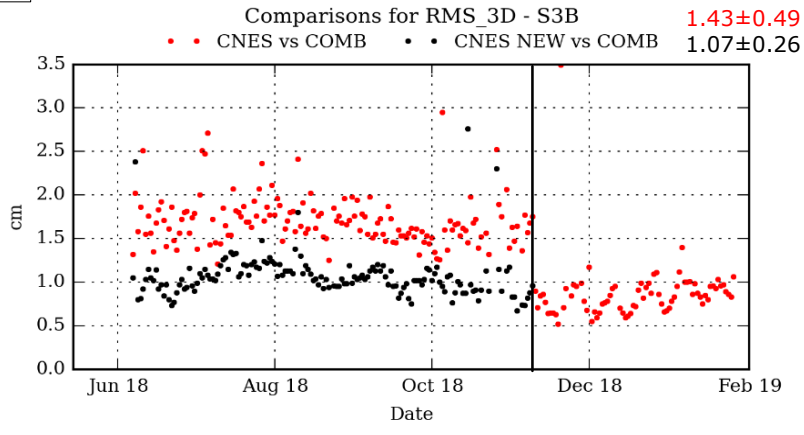

New Standards



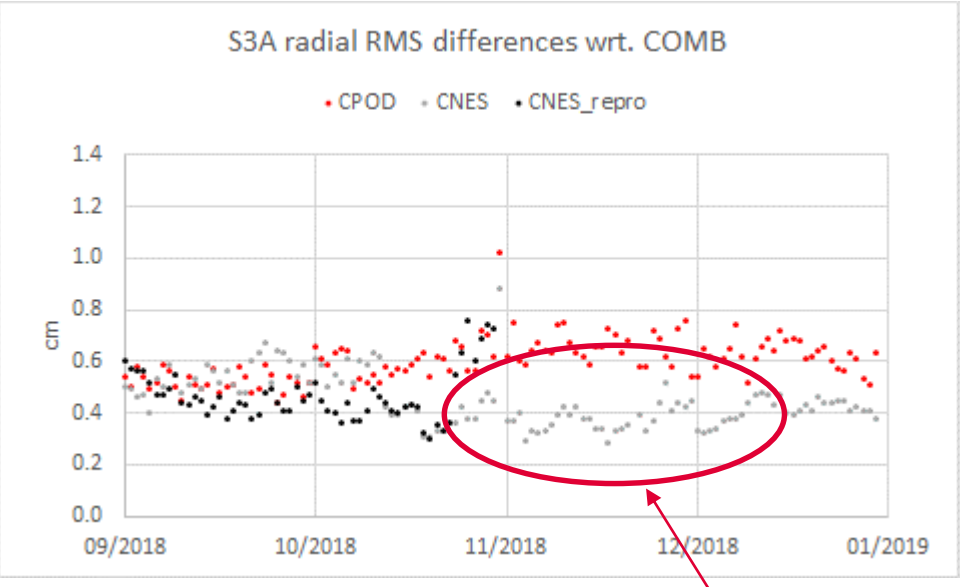

S3B

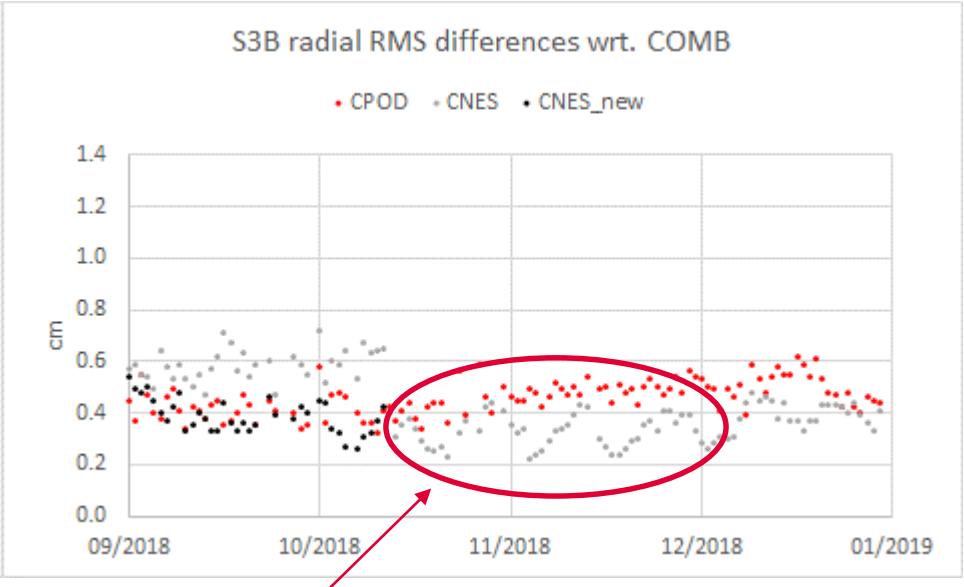
Daily radial RMS

Daily 3D RMS



# OVERVIEW OF SENTINELS POD ACCURACY




Curious oscillating patter

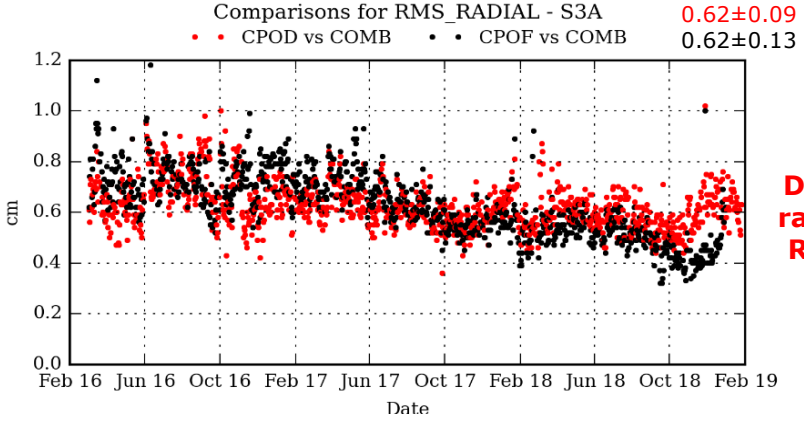
# NEW STANDARDS

- CPOD is currently testing several changes of standards and processing scheme

| | CNES POE-F | CPOD NOW | CPOD FUTURE |
|---|---|---|---|
| Gravity Field | EIGEN-GRGS.**RL04**-v1.MEAN-FIELD | EIGEN.GRGS.RL03.v2 | **EIGEN-GRGS.RL04.MEAN-FIELD** |
| Ocean tides | FES2014 | EOT11a | FES2014 |
| Oceanic/atmospheric gravity | 3hr dealiasing products from GFZ AOD1B RL06 | AGRA | **3hr dealiasing products from GFZ AOD1B RL06** |
| Atmospheric density model | MSIS-00 | MSIS-90 | MSIS-00 / DTM (TBD) |
| Terrestrial Reference Frame | ITRF2014 | ITRF2014 | ITRF2014 |
| Estimated measurement parameters | GPS: fixed ambiguity only for NTC orbits and when possible per pass, receiver clock adjusted per epoch | GPS: floating ambiguity per pass, receiver clock adjusted per epoch | **GPS: fixed ambiguity only for NTC orbits and when possible per pass, receiver clock adjusted per epoch** |

- Test1: **CPOF**: CPOD with current configuration + fixed ambiguities using GRG products (same products used by CNES)
- Test2: **GRL4**: CPOD with new **Gravity Field** and **Oceanic/atmospheric gravity**

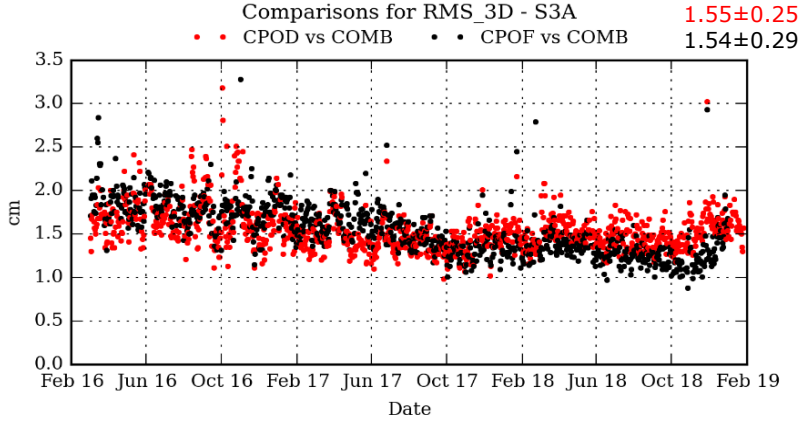
# INTEGER PHASE AMBIGUITY (1/3)

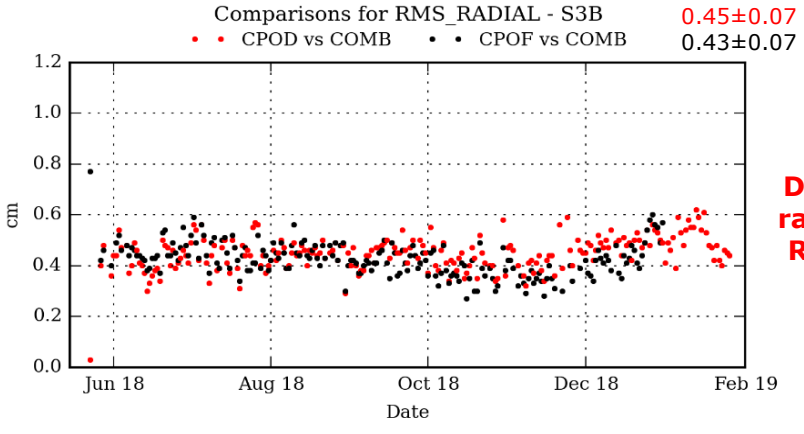



**S3A**

**Daily radial RMS**

**Daily 3D RMS**

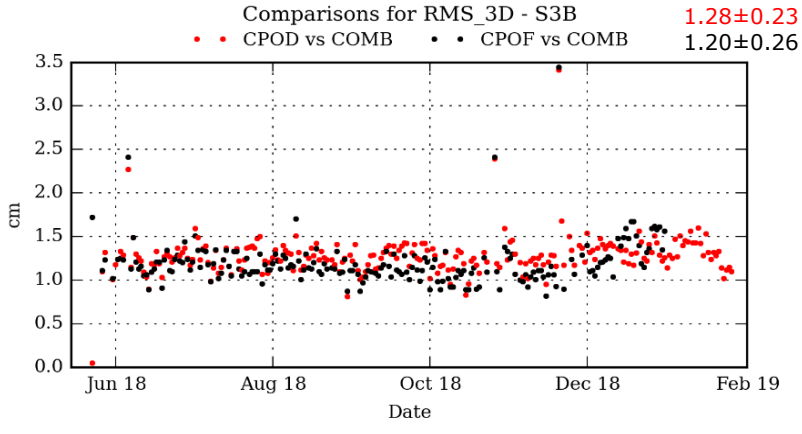


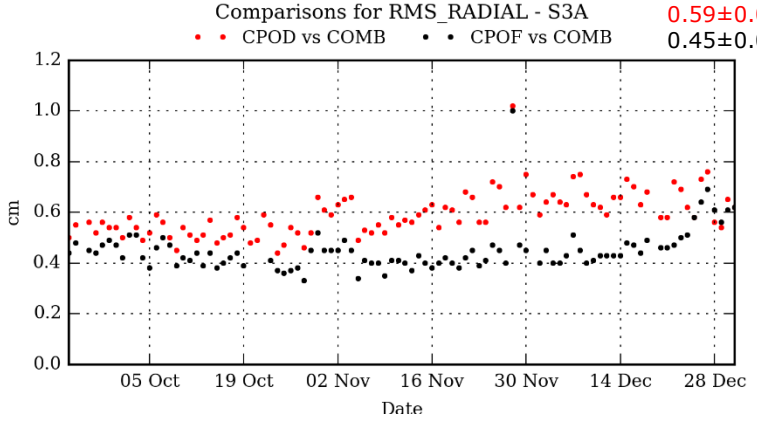

**S3B**

**Daily radial RMS**

**Daily 3D RMS**



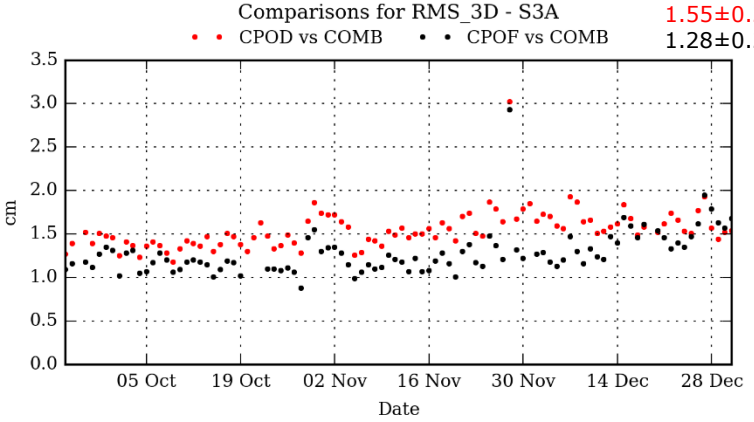
# INTEGER PHASE AMBIGUITY (2/3)

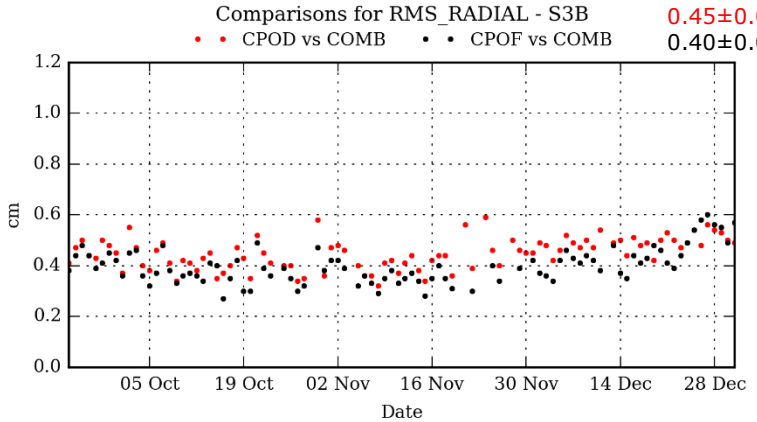



**S3A**

**Daily radial RMS**

**Daily 3D RMS**

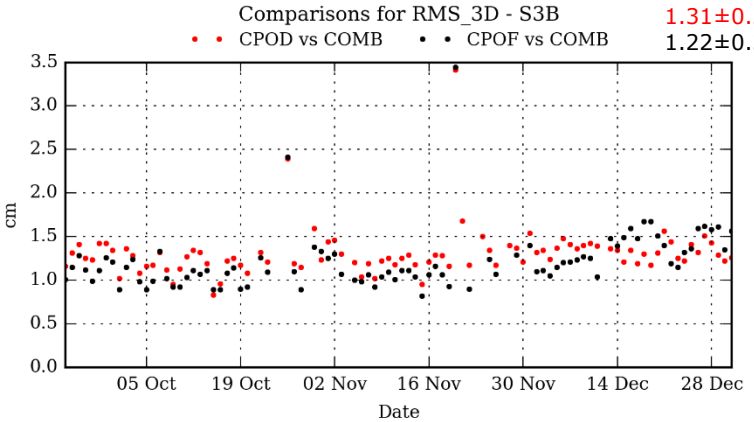



**S3B**

**Daily radial RMS**

**Daily 3D RMS**




The differences wrt. the combine solution improves slightly when applying IAR.

# INTEGER PHASE AMBIGUITY (3/3)

- Current the CPOD solution is based on a float estimation of the phase ambiguity
- The CPOD system is already capable of computing an orbit solution using integer ambiguity resolution techniques
  - Most commonly used: GRG products
  - Alternatives being explored:
    - CODE products
    - GMV products (based on *magicGNSS*)
  - The final option would depend on
    - Availability
    - Performance
    - Future capability for GPS+GALILEO
    - Timeliness (NRT, STC, NTC)

# NEW STANDARDS

- CPOD is currently testing several changes of standards and processing scheme

| | CNES POE-F | CPOD NOW | CPOD FUTURE |
|---|---|---|---|
| Gravity Field | EIGEN-GRGS.**RL04**-v1.MEAN-FIELD | EIGEN.GRGS.RL03.v2 | **EIGEN-GRGS.RL04-v1.MEAN-FIELD** |
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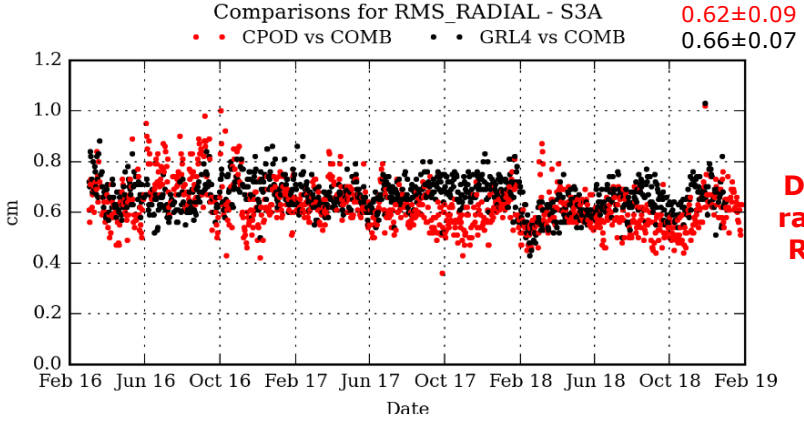
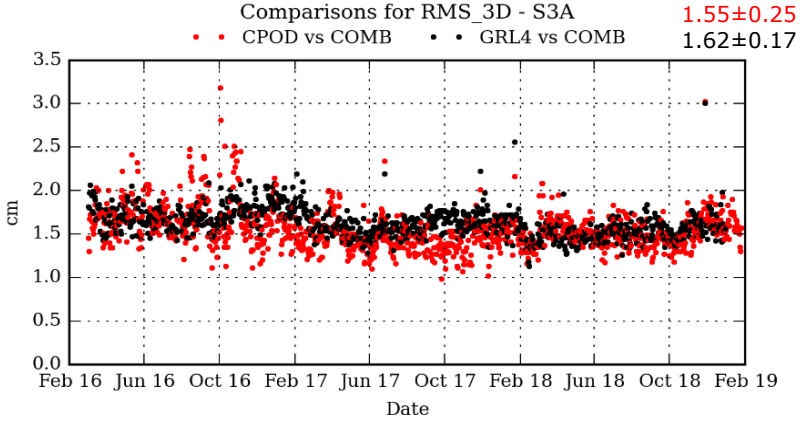
# GRAVITY FIELD & ATMOS. GRAVITY

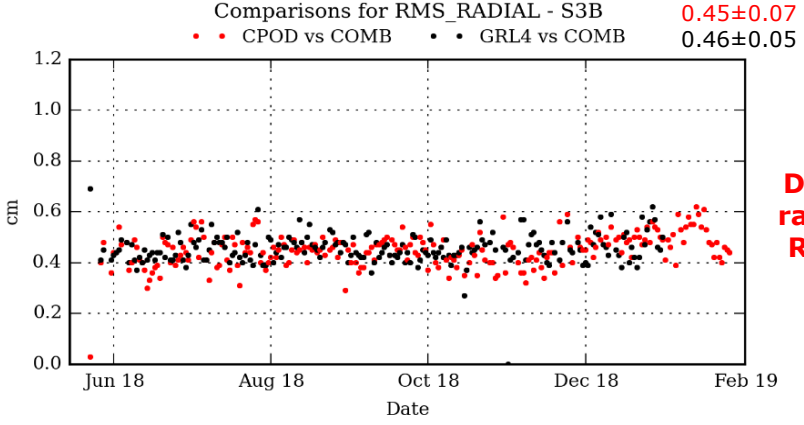



**S3A**

**Daily radial RMS**

**Daily 3D RMS**

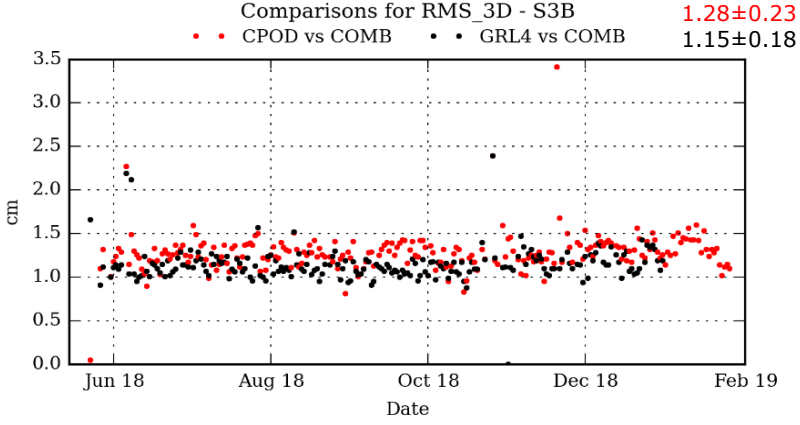



**S3B**

**Daily radial RMS**

**Daily 3D RMS**



# GRAVITY FIELD & ATMOS. GRAVITY

- The following table shows the 2h overlap differences between consecutive orbits.

| 2h overlap (cm) | Current | New | Diff |
|---|---|---|---|
| S-3A | 1.17 ± 0.42 | 0.84 ± 0.32 | 0.33 |
| S-3B | 1.26 ± 0.40 | 0.92 ± 0.30 | 0.34 |

- It shows that the stability of the orbits improves

- We still have to test everything together.

# CONCLUSIONS

- The accuracy of the CPOD orbital solutions of Sentinel-3 A&B maintains the required accuracy.
- New models, standards and approaches are being implemented and tested to improve the accuracy and stability of the orbits.

- The CPOD POD SW is currently able to generate orbits where the GPS phase ambiguities are fixed. However, there are few sources of inputs, and new ones are being tested: CODE and *magicGNSS* (GMV)
  - The solution to be used impacts the timeliness on which can be applied (NRT, STC, NTC)

- New gravity fields and atmospheric gravity models are being tested currently.
- New Ocean tides (FES2014) will be implemented and tested soon.
- Several Atmospheric density model have been implemented and are being tested (MSIS-00, DTM)

- As soon as everything is tested and validated, it will be proposed to the CPOD QWG and ESA/EUMETSAT to agree on a change.


Thank you!
Comments?
Questions?
CPOD Team
INNOVATING SOLUTIONS