# Impact of GPS box-wing models on LEO orbit determination

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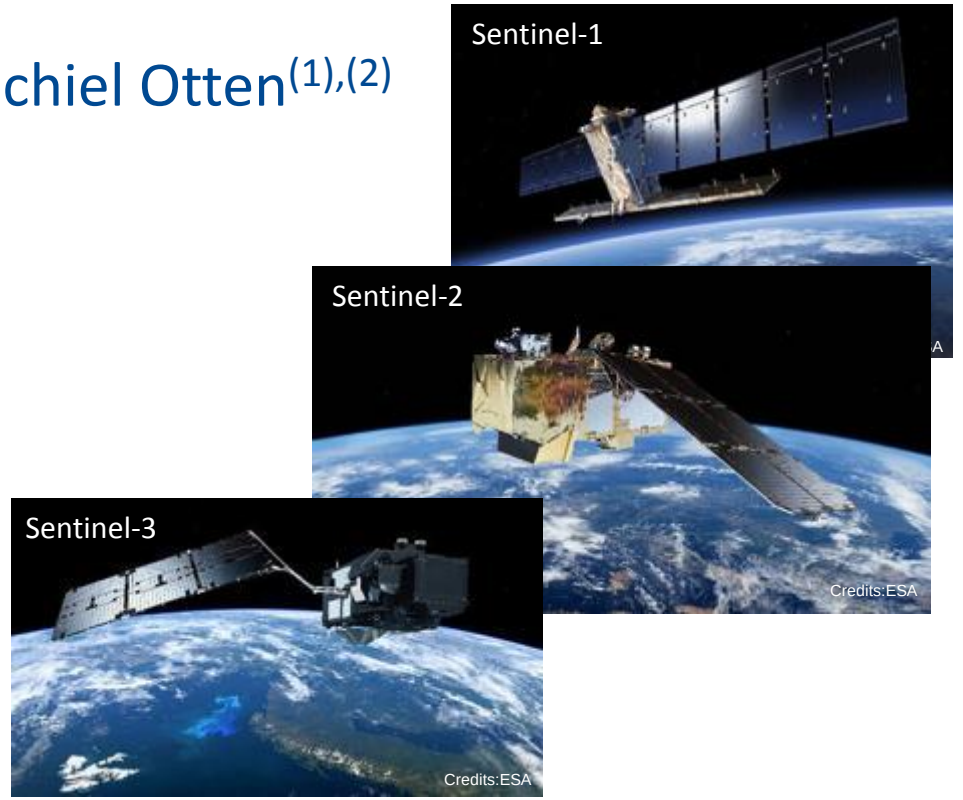



IGS Workshop

3-7 July, 2017

Paris, France

PosiTIM

# Motivation

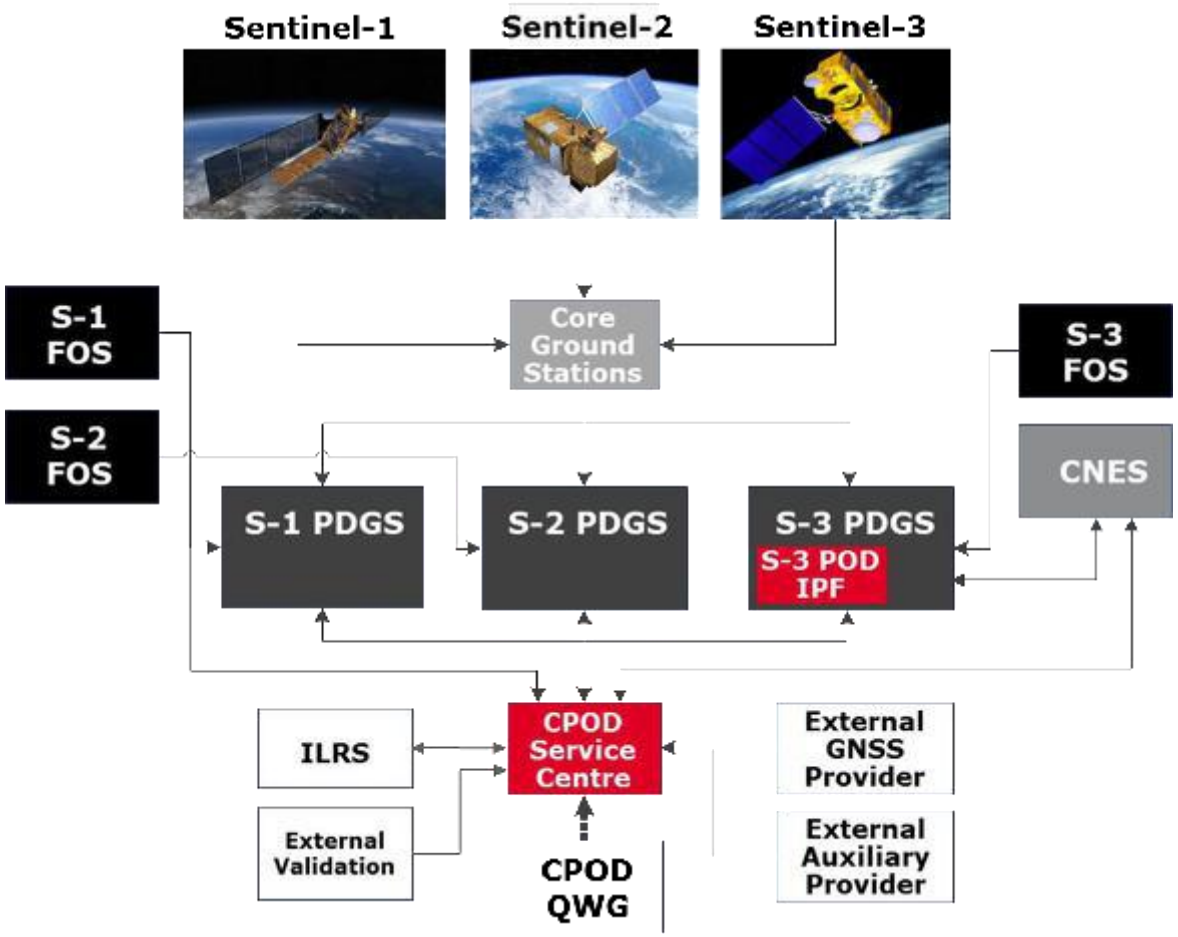
- Copernicus Sentinel POD does for some products rely on IGS products
  - Changes in the IGS products will require reprocessing
  - Can not wait for IGS so do our own reprocessing
  - Our reprocessing results may be a contribution to the IGS reprocessing

- Need for the GPS orbit and clock reprocessing:
  - ITRF2008 => ITRF2014 switch and related IGS Antex change
  - 24h restriction of IGS products

- GPS orbit and clock reprocessing investigations have been started
  - To validate implementation of ITRF2014 and PSD, and usage of IGS14.atx
  - Study use of a solution interval of 36 h (24h + 6h on each end)
  - Orbit modelling of GPS satellites not yet optimized
    - Tune/validate box-wing model for GPS-IIF satellites

- One issue is that the Sentinel PCV maps are based on the ITRF08 and IGS08.atx
  - Significant changes in IGS14.atx compared to IGS08.atx for GPS satellites

# Copernicus POD Overview




- **Copernicus POD Service**: Operational service to provide **accurate orbit and attitude products** for the **Sentinel**-missions
- Software core: **NAPEOS** (Navigation Package for Earth Orbiting Satellites)
- GPS-based orbit determination for the satellites

=> Poster: PS07-04 **The Copernicus POD Service** by Fernández et al.

# Sentinel missions – satellites description

| | SENTINEL MISSIONS | | |
|---|---|---|---|
| | **Sentinel-1** | **Sentinel-2** | **Sentinel-3** |
| **Altitude** | 639 km | 786 km | 814.5 km |
| **Inclination** | 98.18 deg. | 98.58 deg. | 98.65 deg. |
| **Period** | 98.6 minutes | 100.6 minutes | 100.99 minutes |
| **Cycle** | 12 days | 10 days | 27 days |
| **Mass** | 2300 kg | 1140 kg | 1250 kg |
| **GPS** | 2 GPS receivers | 2 GPS receivers | 2 GPS receivers |
| **LRR** | None | None | 1 LRR |
| **DORIS** | None | None | 1 DORIS |
| **Attitude** | Zero-Doppler + roll steering | Yaw steering | Yaw steering |
| **Instruments** | C-Band SAR | Multi-Spectral Instrument | Radar Altimeter, OLCI, Microwave Radiometer |
| **Launch date** | 3rd April, 2014 (S1A)<br>22nd April, 2016 (S1B) | 23rd June, 2015 (S2A)<br>7th March, 2017 (S2B) | 16th February, 2016 (S3A)<br>Expected spring 2018 (S3B) |
| **Picture** |  |  |  |

# Sentinel Requirements

| Mission | Category | Orbit Accuracy (RMS) | Latency | Coverage |
|---|---|---|---|---|
| S-1 | NRT | 10 cm (2D) | 180 min | 2 orbits |
| | **NTC** | 5 cm (3D) | 20 days | **26 h** |
| S-2 | NRT (pred.) | 3 m (2D) | 90 min before ANX | 2 orbits |
| | NRT | 1 m (3D) | 30 min | Received PVT span + 2 orbits backwards |
| S-3 | NRT | 10 cm radial (target of 8 cm) | 30 min | Received PVT span + 5 OSV before and after |
| | STC | 4 cm radial (target of 3 cm) | 1.5 days | 26 h |
| | **NTC** | 3 cm radial (target of 2 cm) | 25 days | **26 h** |

- **The non time-critical (NTC) orbit products make use of the IGS Final orbit and 30 sec clock products**

- Due to a coverage > 24h, three consecutive days of the IGS Finals have to be concatenated
  - Orbit and clock discontinuities at midnight
- Switch to ITRF2014 on 29 Jan 2017 => inconsistent time series => Reprocessing necessary

# GPS Reprocessing Investigations

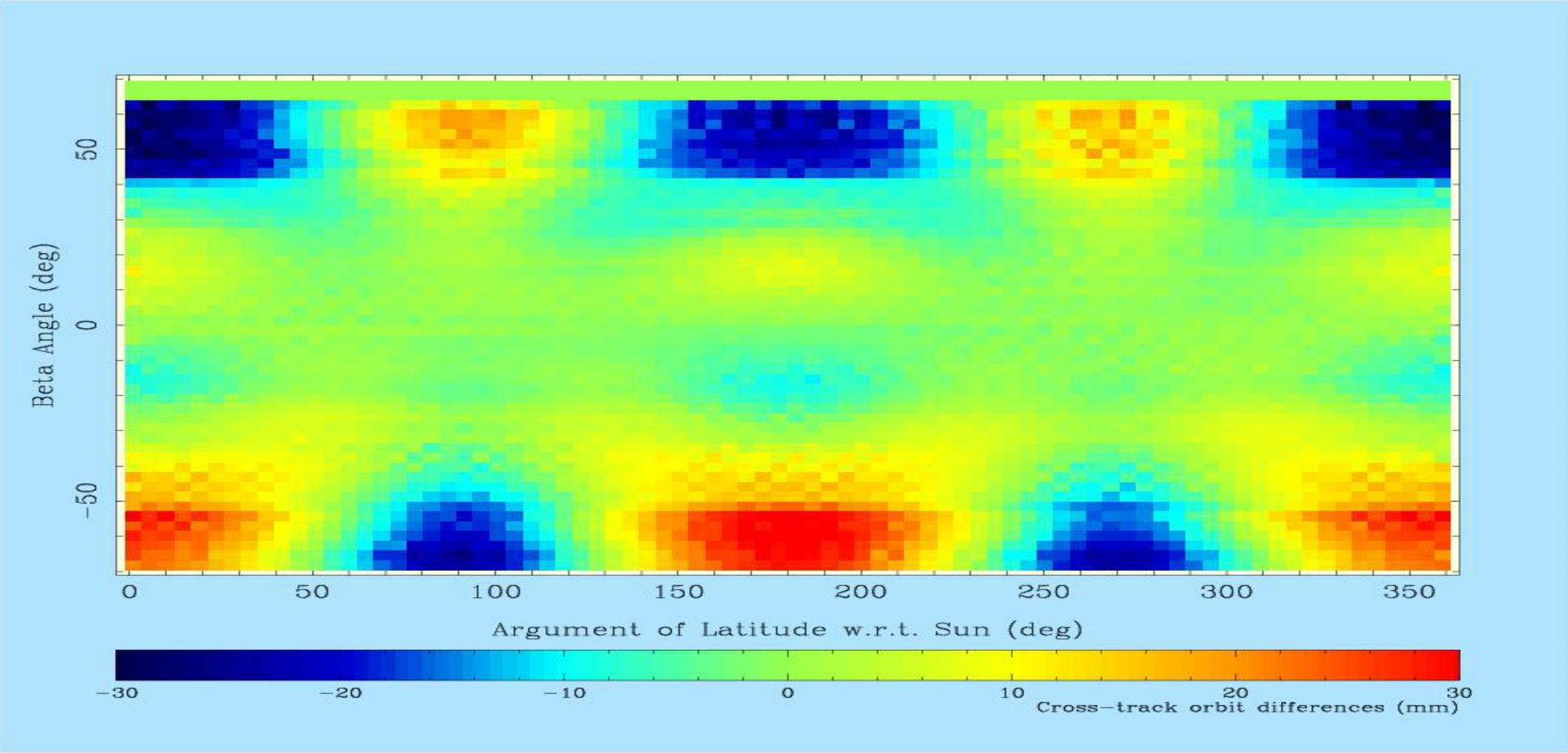
- Generated 4 different solutions using first 130 days of 2017
  - sol1: no a priori model
  - sol5: IGS box-wing model
  - sol4: Tuned box-wing model for the GPS-IIF satellites, IGS values for GPS-IIR
  - sol3: Tuned box-wing model with reradiation
    - Based on GPS orbit overlap statistics sol4 “the best”

- Differences between the solutions only at the 10-20 mm level sigma, largest in radial component
  - Relative differences (sol1 vs sol5, sol5 vs sol4, sol4 vs sol3):

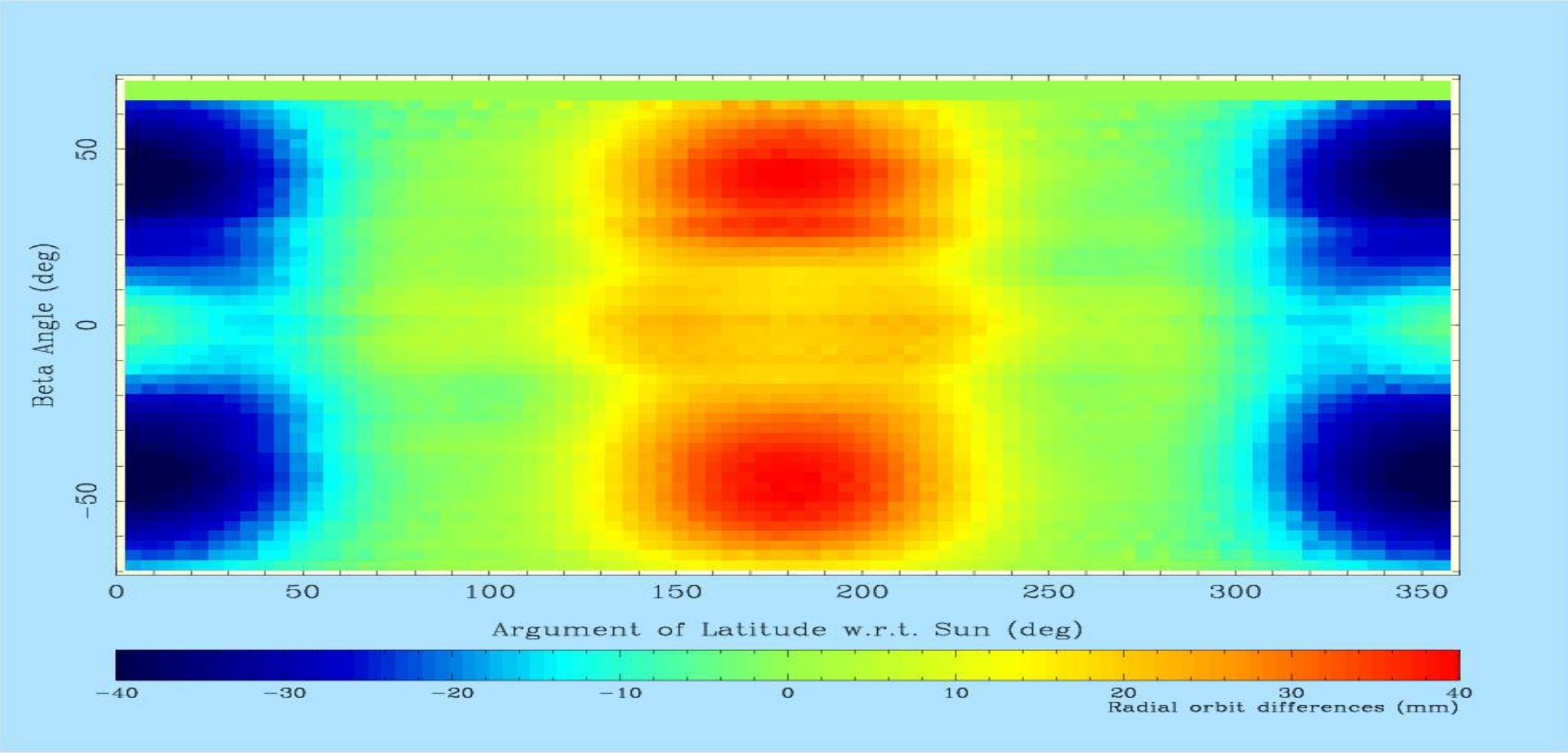
| | IGS BW | Tuned | Rerad |
|---|---|---|---|
| Radial | 19 | 12 | 9 |
| Along | 10 | 4 | 4 |
| Cross | 11 | 6 | 4 |

  - But very systematic (see plots on next slides) and significant mean in cross-track

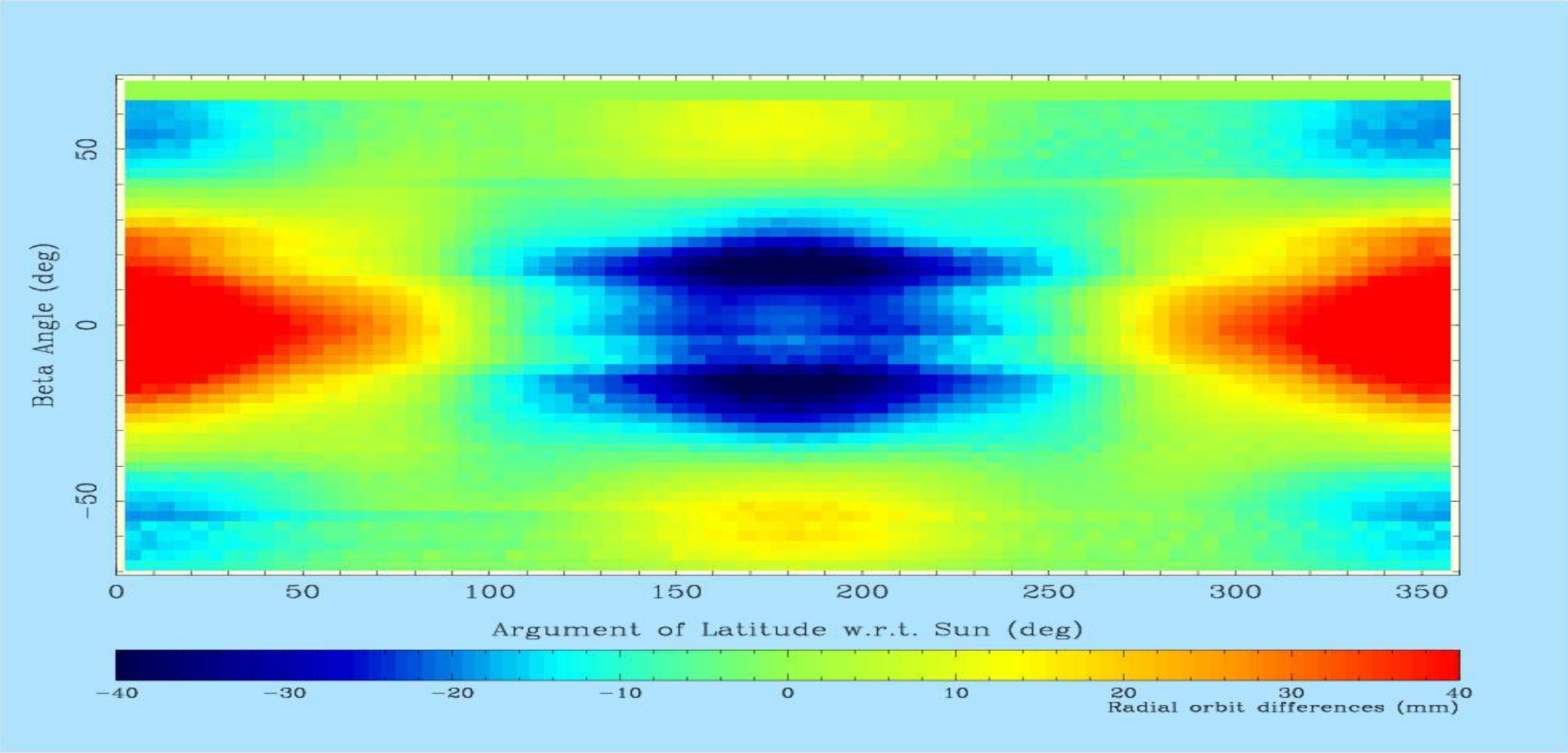
# Cross-track Orbit Differences



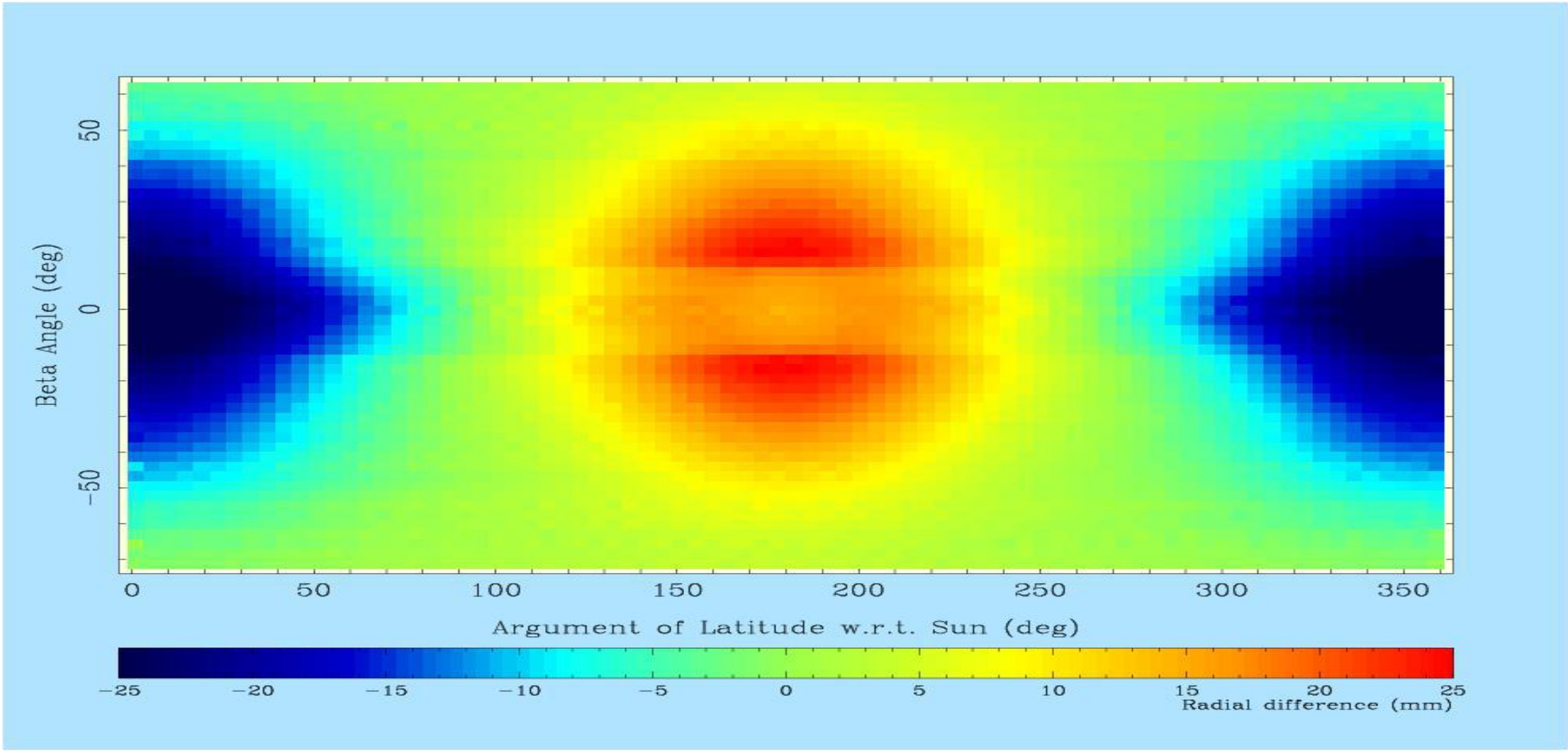
# Radial Orbit Differences (IIR sats only)



# Radial Orbit Differences (IIF sats only)



# Tuned Radial Orbit Differences (IIF only)



# Resulting LEO Orbit Differences

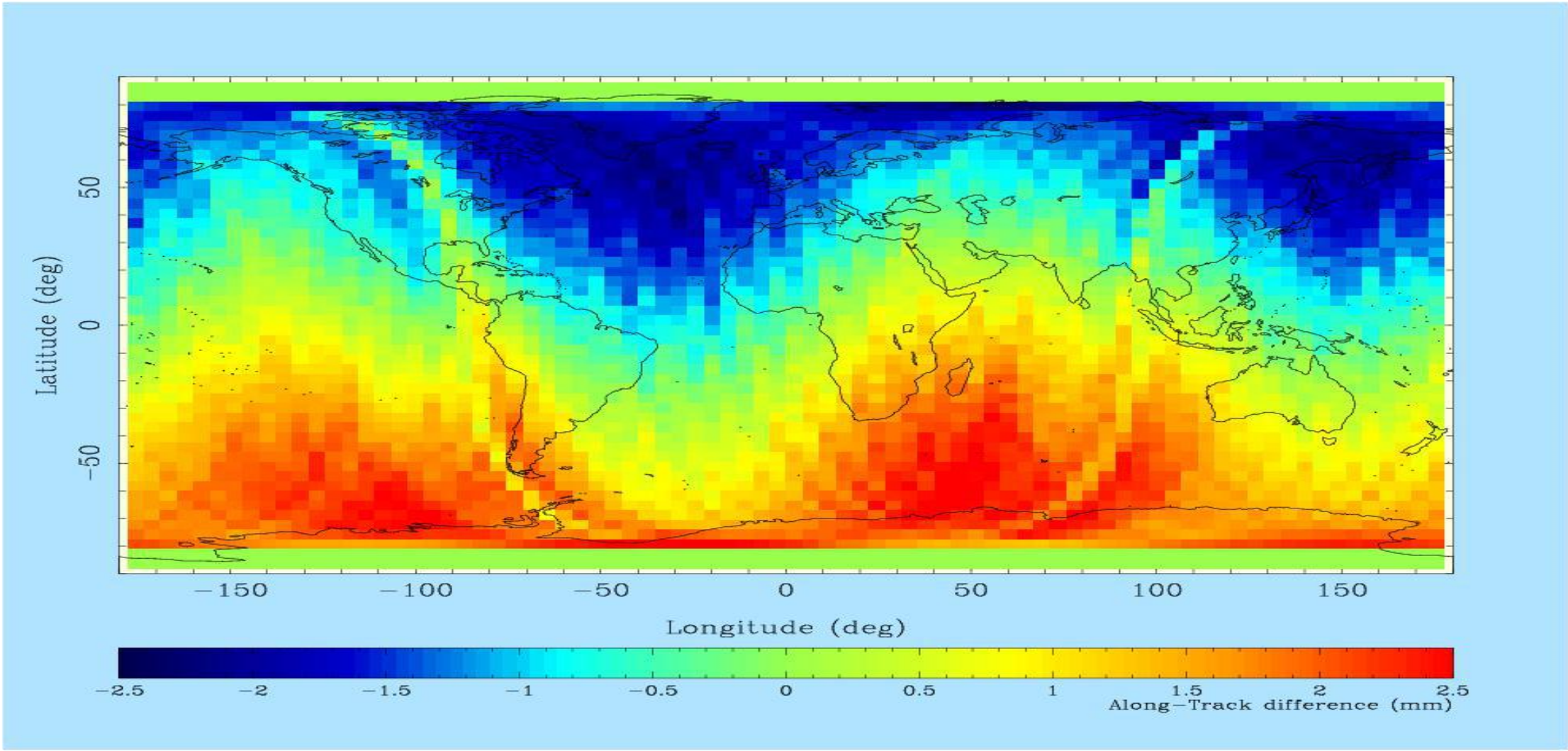
- Differences between the solutions only at the few mm level RMS, largest in cross-track component
  - Solution 1 vs 5 – 5 vs 4 – 4 vs 3

| | IGS BW | Tuned | Rerad |
|---|---|---|---|
| Radial | 1.3 | 0.6 | 0 |
| Along | 2.6 | 1.1 | 0 |
| Cross | 3.1 / -7 | 1. 1 / -2 | 0 |

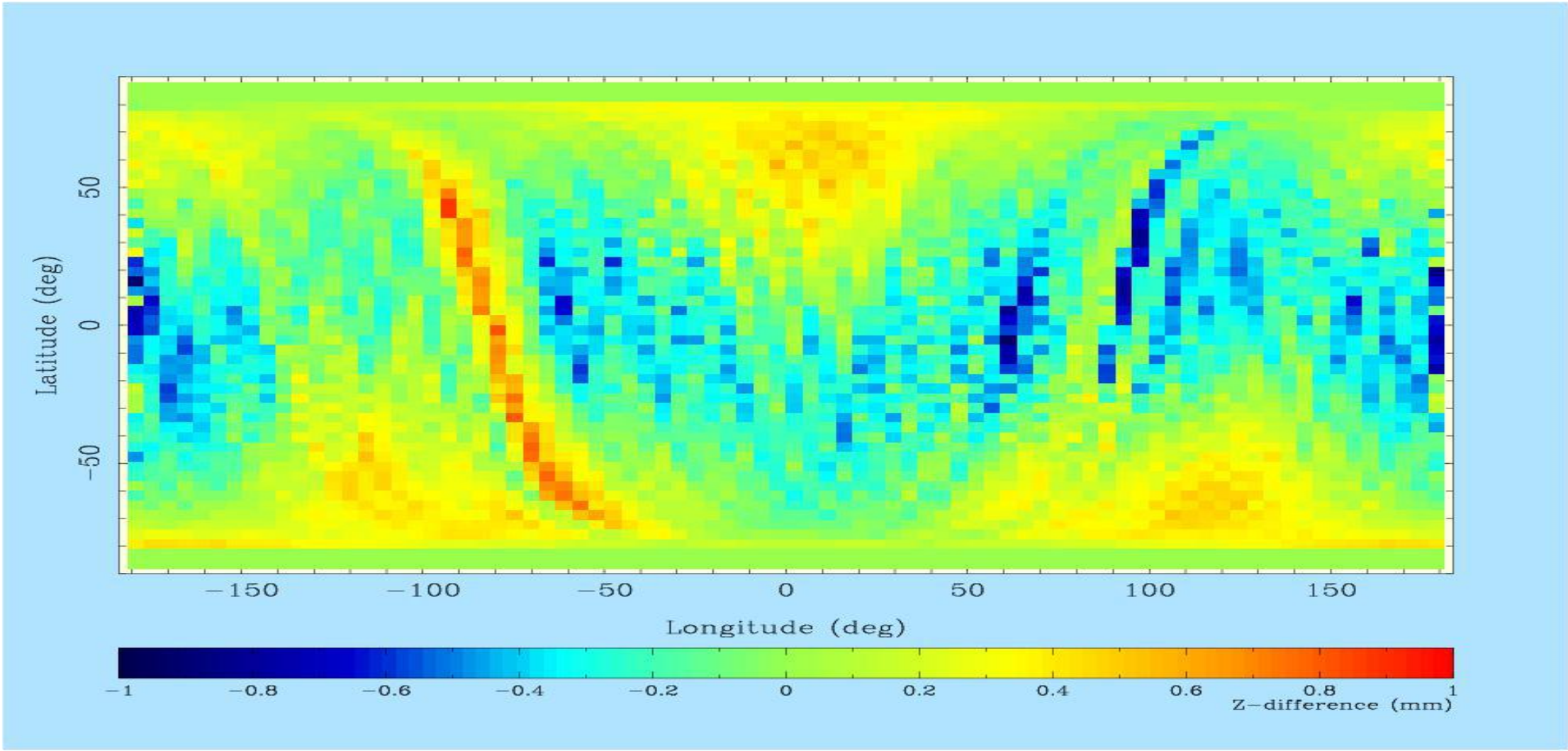
  - Cross-track non-zero mean: -7 – -2
  - Small differences but very systematic (see plots on next slides)
- Solution 1 vs 5: Effect of box-wing
  - Radial noise only
  - Cross-track clear signal with non-zero mean
  - Along-track and Earth-Fixed Z Interesting patterns as function of longitude and latitude
    - See following plots

# Cross-track Orbit Differences

# Along-track Orbit Differences



# Earth-Fixed Z-direction orbit differences

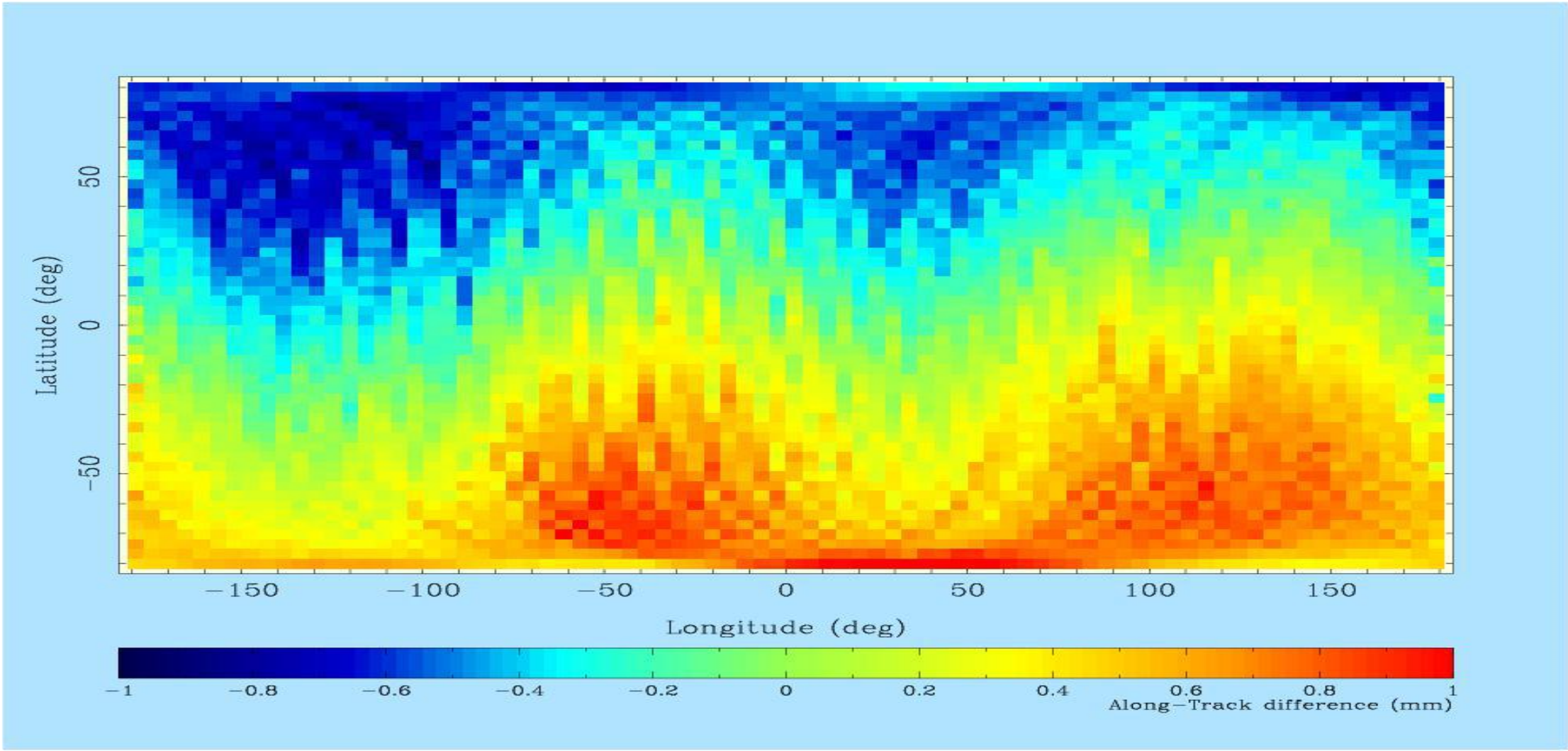


# Resulting Orbit Differences

- Solution 5 vs 4: Effect of tuning IIF satellite box-wing
  - Radial noise only
  - Cross-track clear signal with non-zero mean
  - Along-track interesting patterns as function of longitude and latitude
    - See following plots

# Cross-track Orbit Differences

# Along-track Orbit Differences



# Conclusions

- Sentinel mission depends on IGS final products
  - But in return is able to contribute to IGS reprocessing efforts!

- Significant modeling issues persist in the IGS GPS orbit products
  - These have systematic influences on the LEO solutions
  - This may have an impact on the scientific results obtained with these LEO satellites
  - More and better information regarding the satellites needed!

- Day boundary effect of IGS 24 hour solutions
  - Not really noticeable
  - Nevertheless Sentinel reprocessing considers to deliver 36h solutions

Acknowledgements:
The Copernicus POD Service is financed under ESA contract no. 4000108273/13/1-NB, which is gratefully acknowledged.
The work performed in the frame of this contract is carried out with funding by the European Union. The views expressed herein can in no way be taken to reflect the official opinion of either the European Union or the European Space Agency.