An overview of radio occultation activities at GFZ Potsdam: data processing and applications

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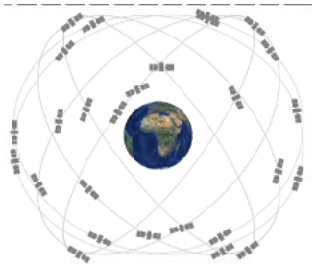
(GFZ Potsdam)

With contributions from JPL (Byron Iijima et al.)

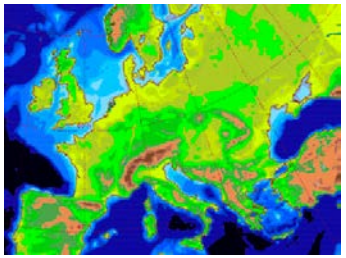
Radio occultation processing system

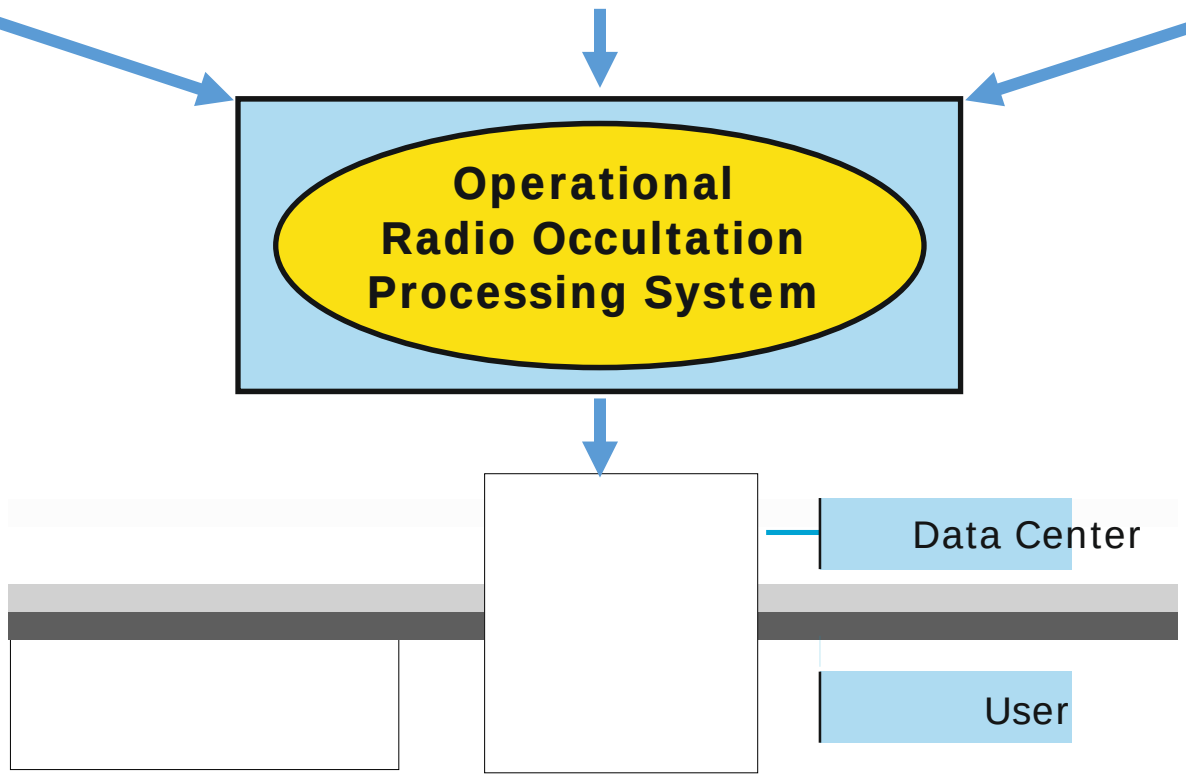
LEO data via GFZ polar receiving station

GPS and LEO orbits from GFZ orbit group

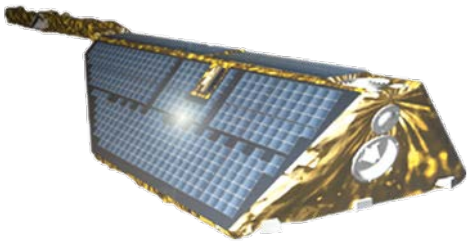


External weather data for validation (ECMWF)

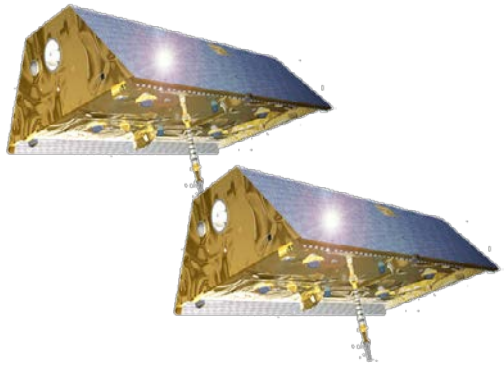




GFZ Radio Occultation Missions

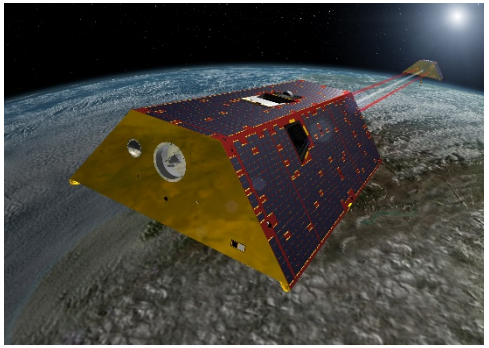


CHAMP
2001-2008
setting



GRACE A/B
2006-2017
setting

TerraSAR-X since 2008, setting
Tandem-X since 2011, rising

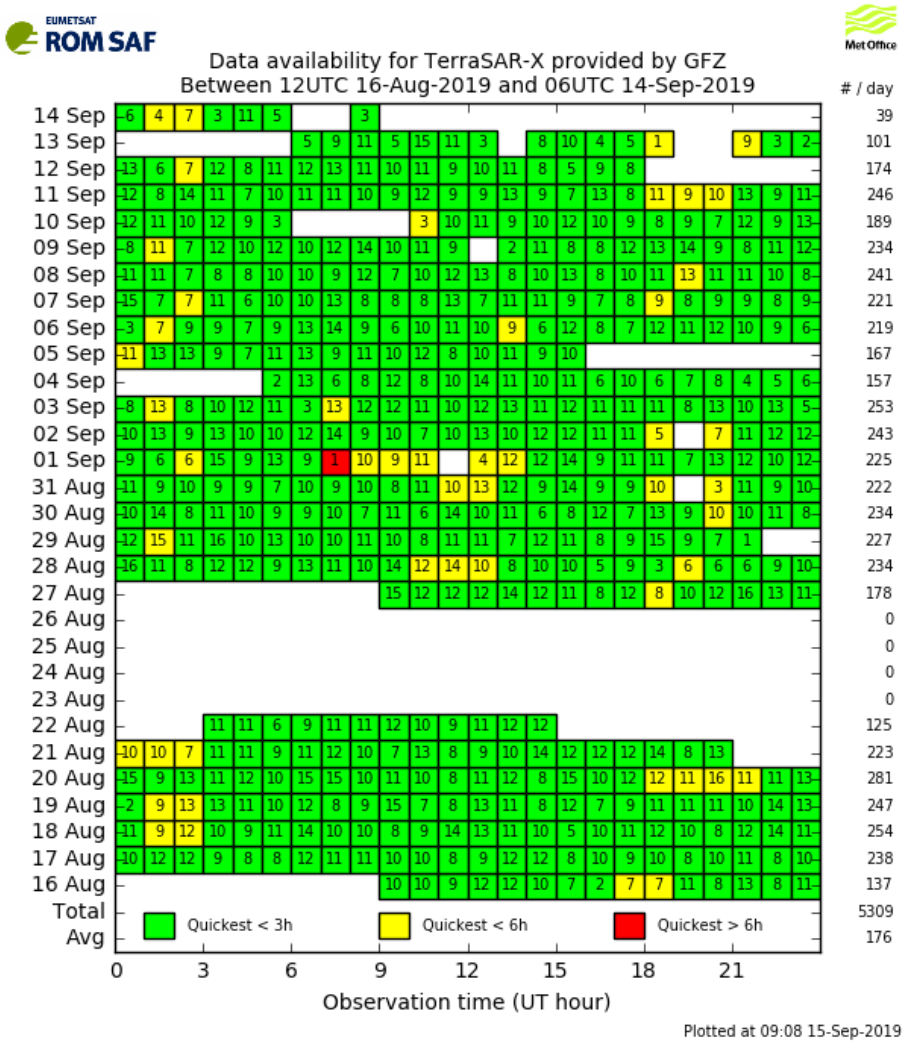


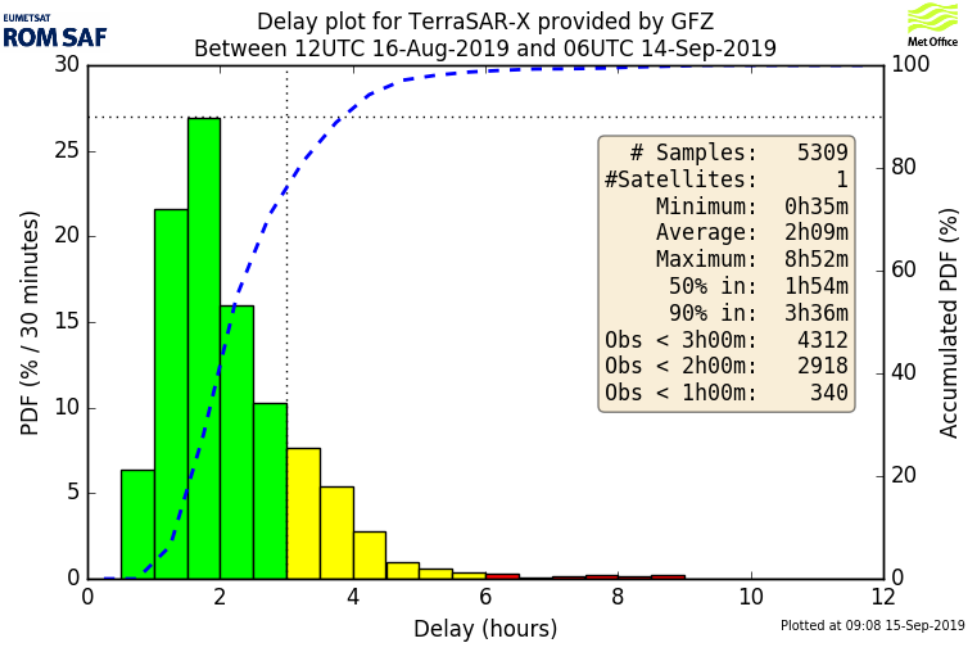
GRACE Follow-on
GRACE C/D
since 2019

GRACE C, rising

Example: TerraSAR-X data delivery

16 Aug to 14 Sep 2019





Mean time delay between onboard measurements and data availability is about 2 hours.

About 90% of all data are delivered within 3 hours.

GRACE Follow-on

Some milestones

- Launched on May 22, 2018.
- Twin satellites follow each other in orbit (in about 490 km) separated by about 200 km.
- Send constantly microwave and laser signals to each other to measure the distance between them. → Gravity field estimation → Main goal of the mission!
- Summer 2018 problems with IPU on GF2 (switched to second IPU in autumn 2018)
- After some (setting) test ROs from GF2 in summer 2018 no ROs for about one year
- Continuous ROs from GF1 (rising occs) since June 14, 2019
- Updated RO reader provided by JPL on July 25

Jet Propulsion Laboratory
California Institute of Technology

GRACE-FO Instrument Processing Unit

Courtesy of Thomas Meehan and Jeffrey Tien

- Based on TriG-Lite design
- Ka/K band tracking for micron-level inter-satellite ranging measurement
- Track up to 12 dual frequency GPS Satellite
  - Real-time PVT (position/velocity/timing)
  - 1-sec pseudorange and phase measurements for post-processed precise orbit determination (POD)
- GPS radio occultation
  - L1CA/L2P, L1CA/L2C, or L1CA/L5
  - Rising radio occultation on the leading satellite
  - Setting radio occultation on the trailing satellite
  - Up to 300 profiles per day per satellite
- Programmable RF downconverter able to receive all L band signal
  - Reconfigurable Software allows additional capabilities (e.g. Galileo GNSS RO) to be added later

GPS radio occultation antenna

Zenith pointing GPS antenna

Instrument Processing Unit (IPU)

GRACE Follow-on data processing

RO reader (from JPL) output

Courtesy of Angela Dorsey, JPL

Currently tracking L1CA, L2P, L5 (prn30, prn32), L2C RO is currently disabled.

- I_Sig1 In-phase correlation product for signal 1 (L1 CA) over 1/numPoints seconds
- Q_Sig1 Quadrature correlation product for signal 1 (L1 CA) over 1/numPoints seconds
- I_Sig2 In-phase correlation product for signal 2 (L2P, L2C, or L5) over 1/numPoints seconds
- Q_Sig2 Quadrature correlation product for signal 2 (L2P, L2C, or L5) over 1/numPoints seconds
- phaseModelSig1 CA model (cy)
- phaseModelSig2 P2/L5 model (cy)
- pseudoRangeSig1 CA pseudorange (m)
- pseudoRangeSig2 P2/L2C/L5 pseudorange (m)

In CL I_Sig1 = 50Hz amplitude for CA, Q_Sig1=0, I_Sig2 = 50Hz amplitude for P2/L2C/L5, Q_Sig2=0

```
617199765 0.427297960 OL prn9  -7612  11941  -4099  -2851  61507796.511785  89457943.403831  29171682.617979  29171700.762967
617199765 0.447297564 OL prn9  -10817  9227  -5143  -6441  61507172.199523  89457456.939741  29171682.617979  29171700.762967
617199765 0.467297168 OL prn9  -13249  6762  -5934  -14352  61506547.885446  89456970.586664  29171682.617979  29171700.762967
617199765 0.487296772 OL prn9  -14703  2141  -6845  -21014  61505923.569677  89456484.070308  29171682.617979  29171700.762967
617199766 -0.500 CL prn9  14911  0  451  0  61505527.019257  89456174.785529  29165741.606538  29165750.345726
617199766 -0.480 CL prn9  15111  0  93  0  61504902.646376  89455688.454518  29165741.606538  29165750.345726
617199766 -0.460 CL prn9  15571  0  2225  0  61504278.256473  89455202.088007  29165741.606538  29165750.345726
617199766 -0.440 CL prn9  15854  0  1211  0  61503653.873963  89454715.542321  29165741.606538  29165750.345726
```

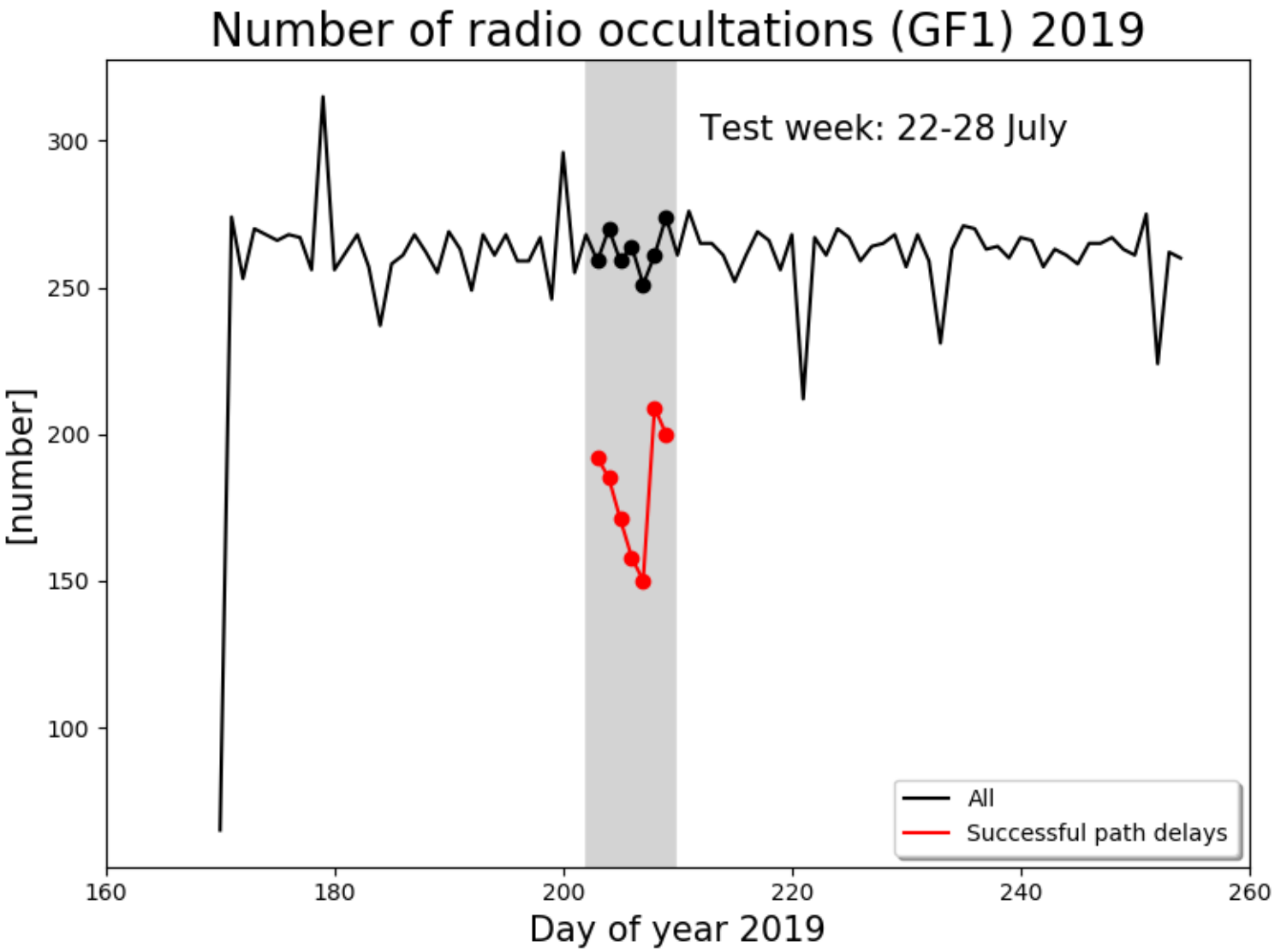
OL: $TotalPhase = PhaseModelSig + \frac{atan2(Q_{Sig} * B, I_{Sig} * B)}{2\pi} + C_n$

CL: $TotalPhase = PhaseModelSig$

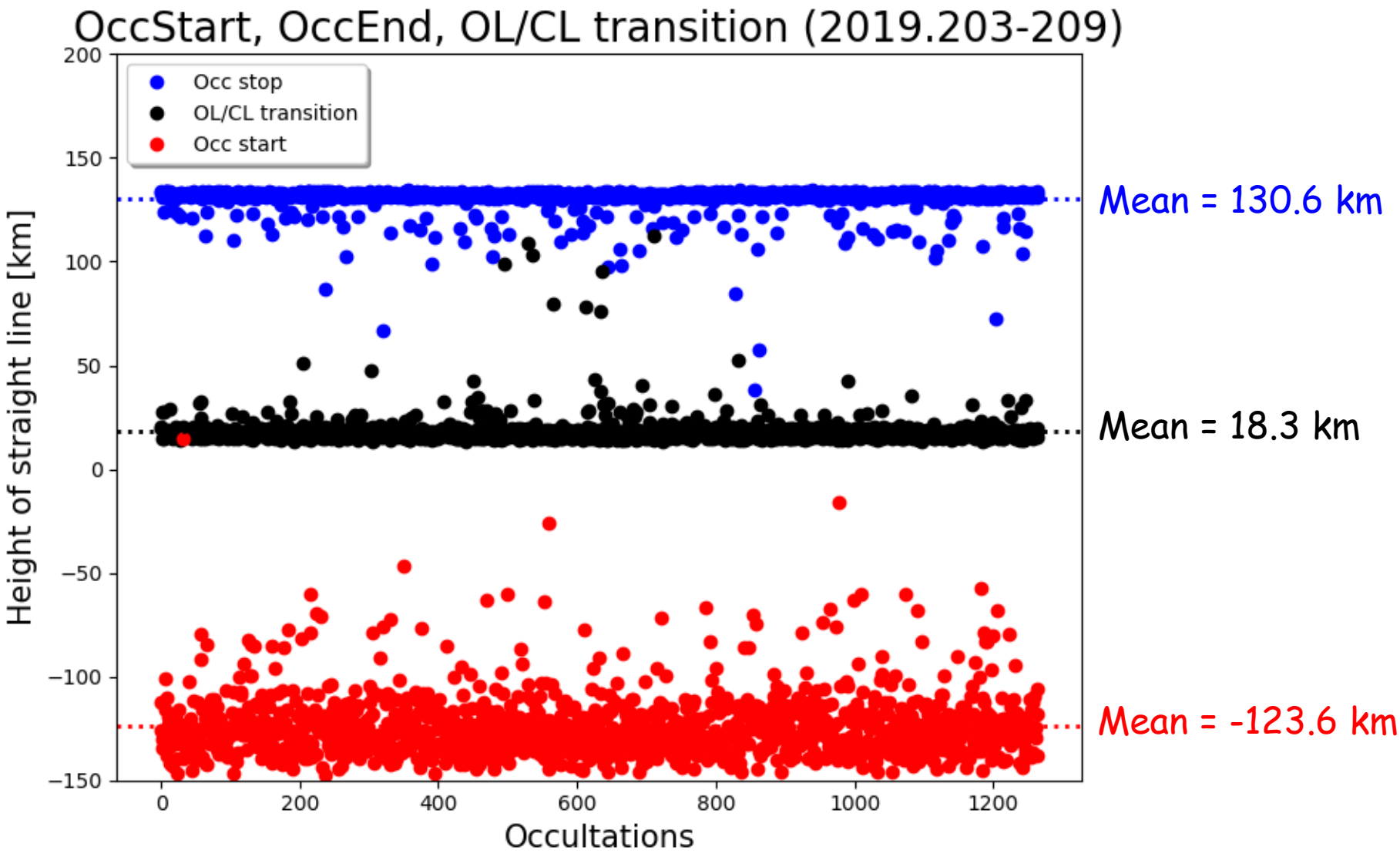
B: navbit correction

C_n: phase unwrapping

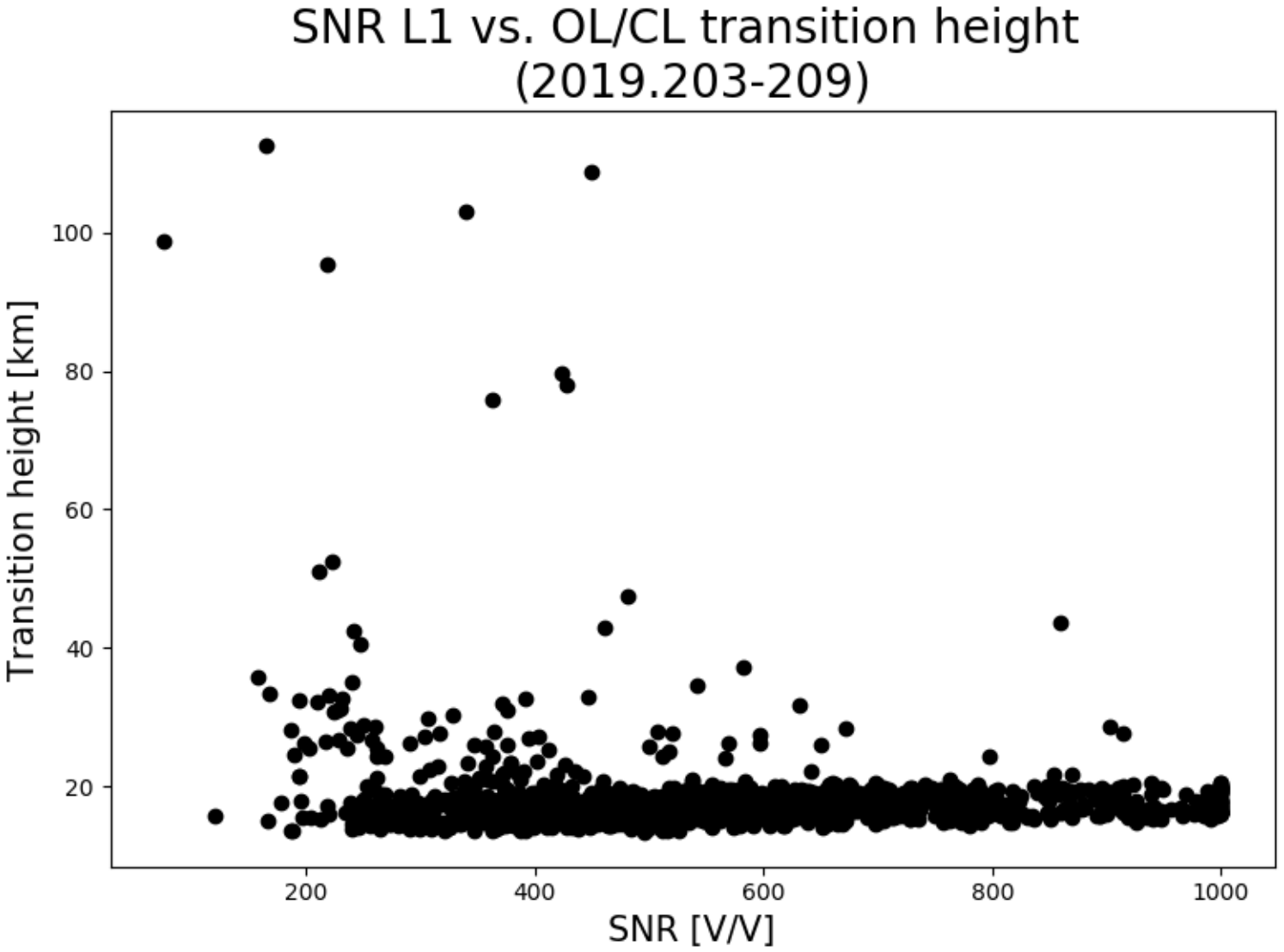
GRACE Follow-on data processing



GRACE Follow-on data processing

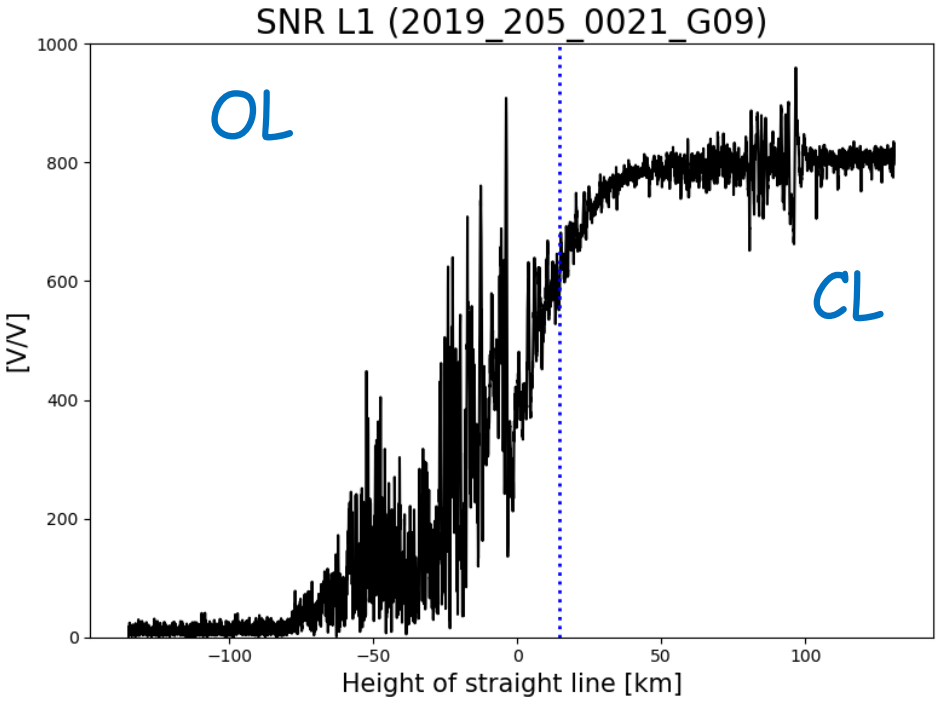


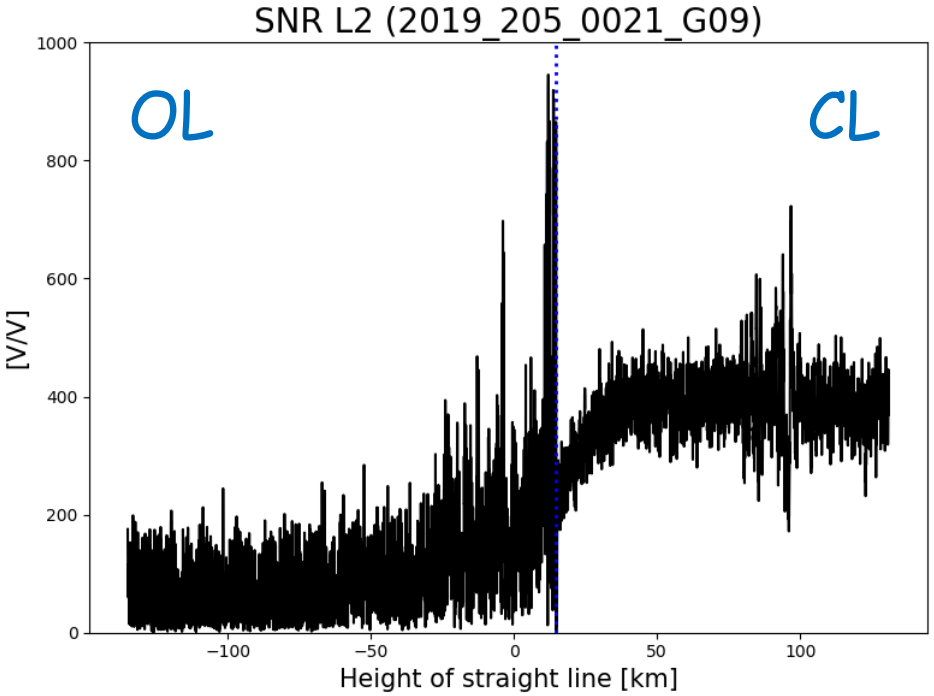
GRACE Follow-on data processing



GRACE Follow-on data processing

SNR $OL: SNR = Factor * \sqrt{(I^2 + Q^2)}$ $CL: SNR = Factor * Ampl$





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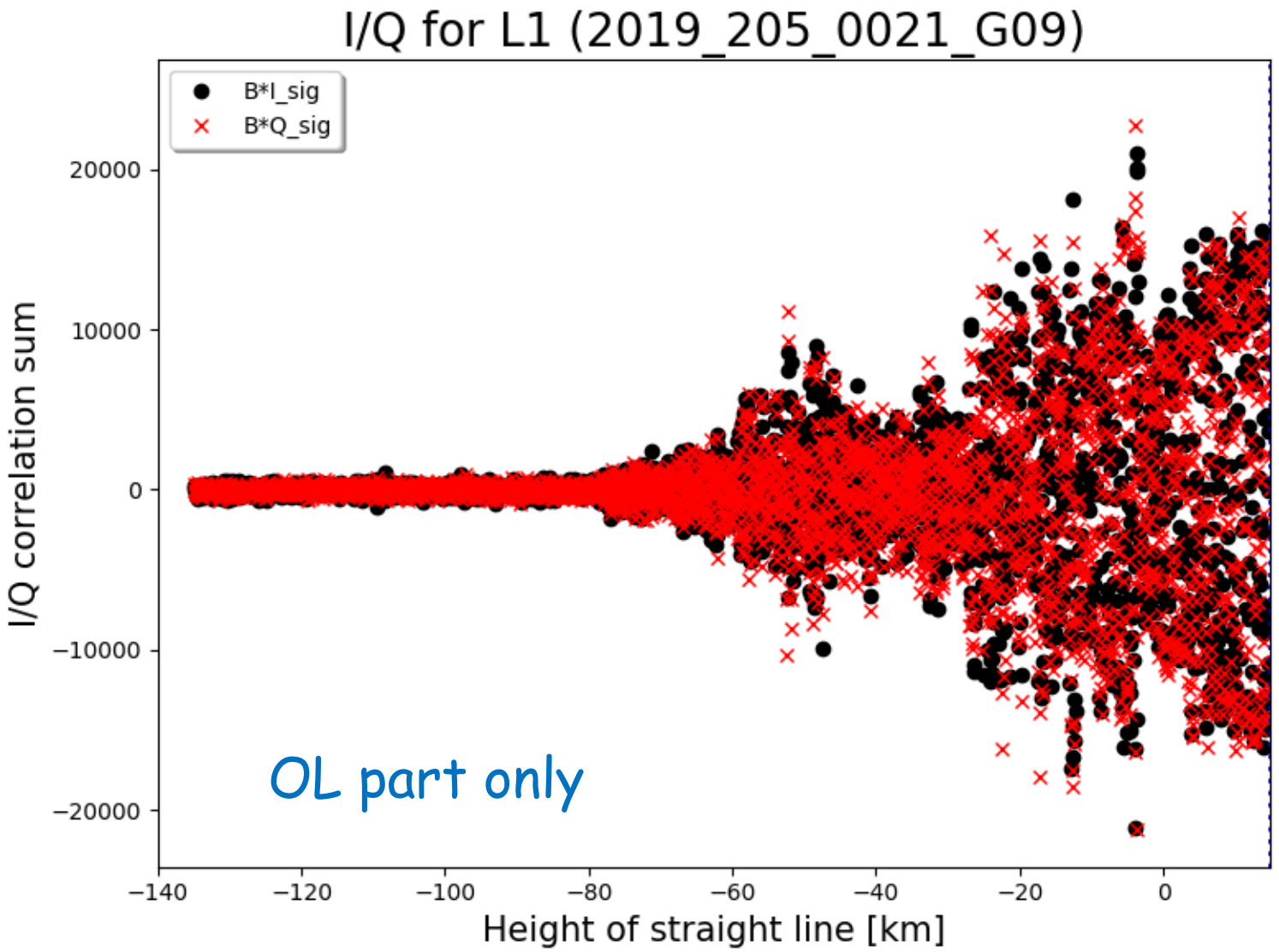

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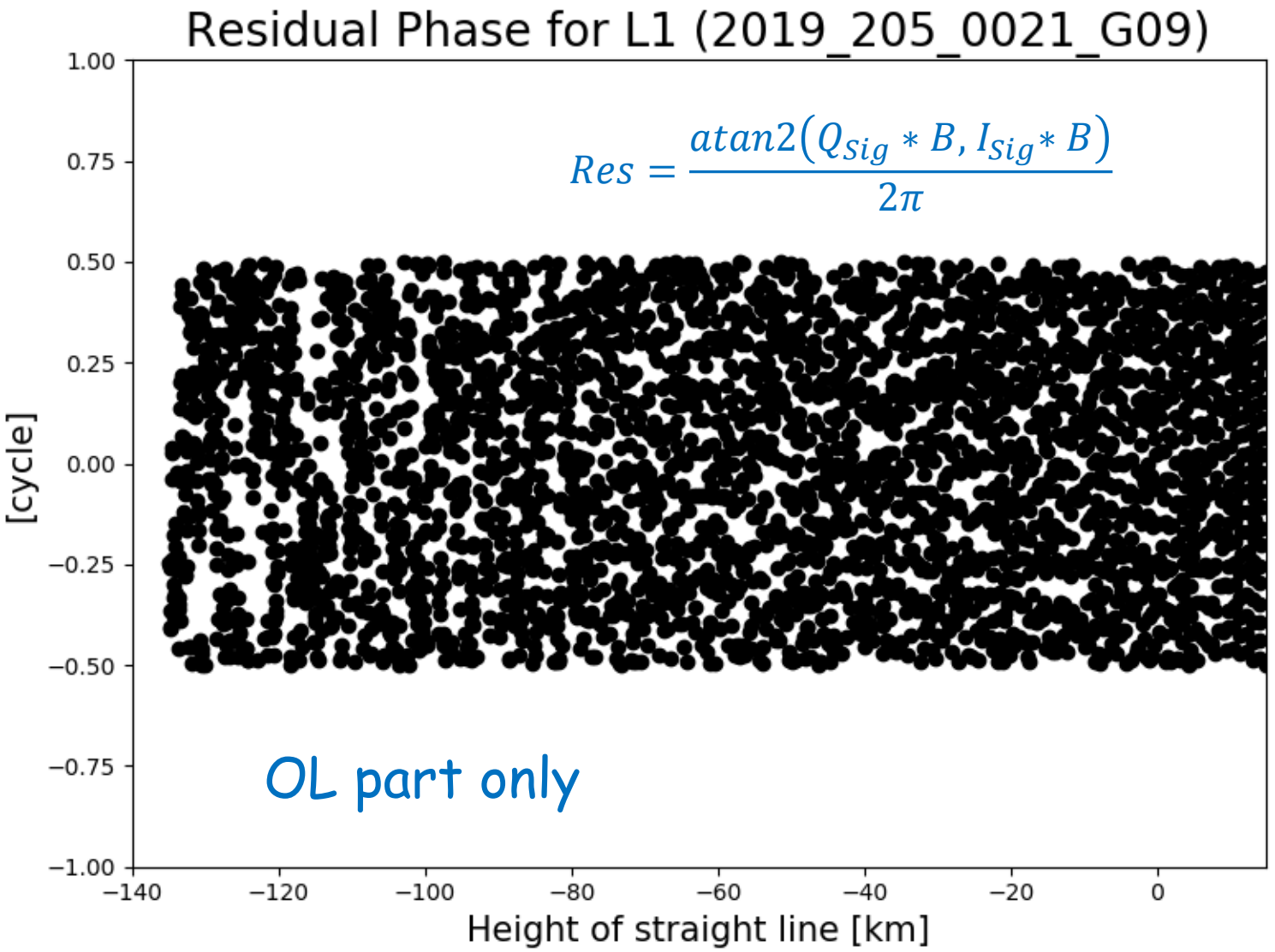

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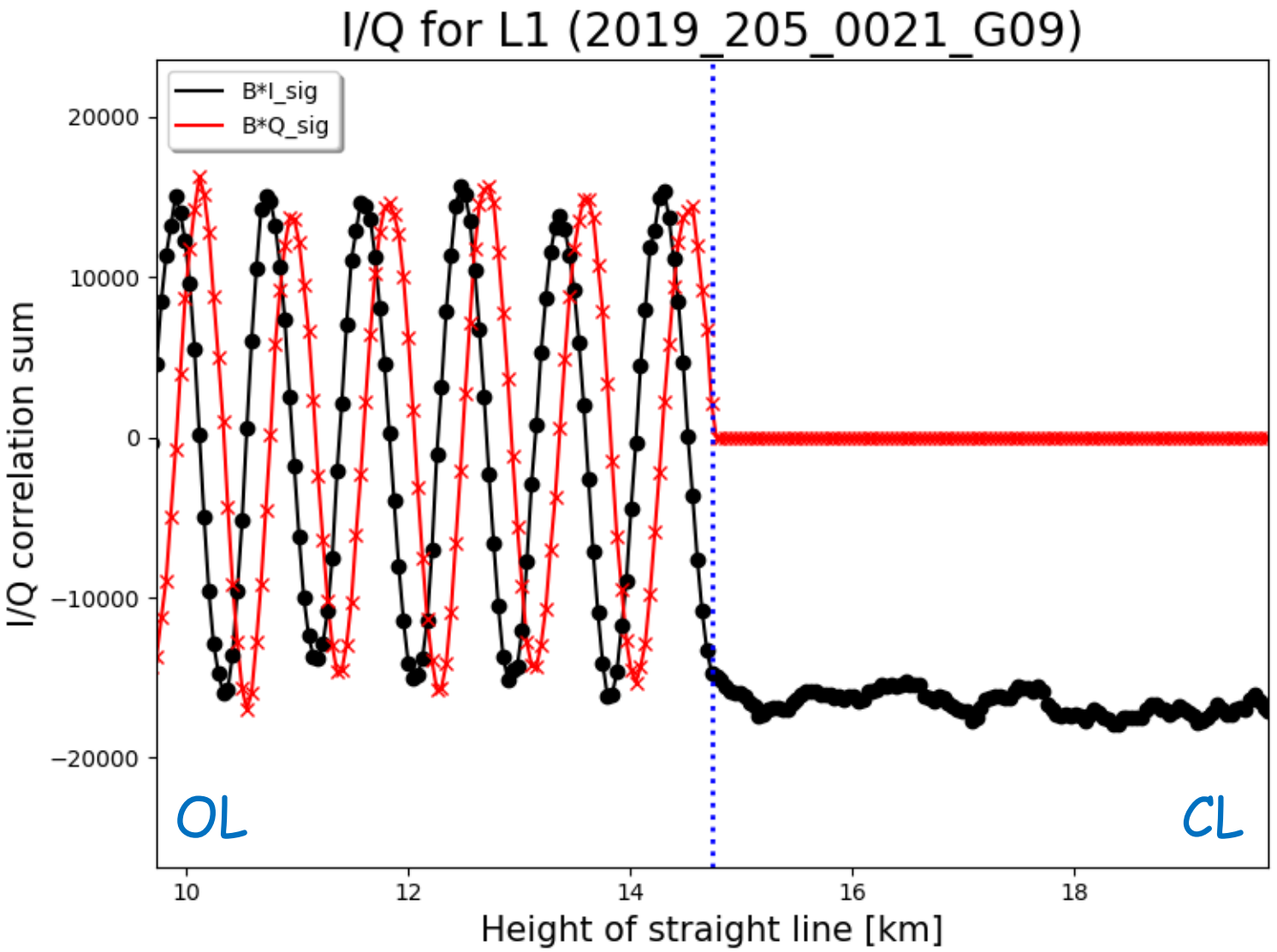

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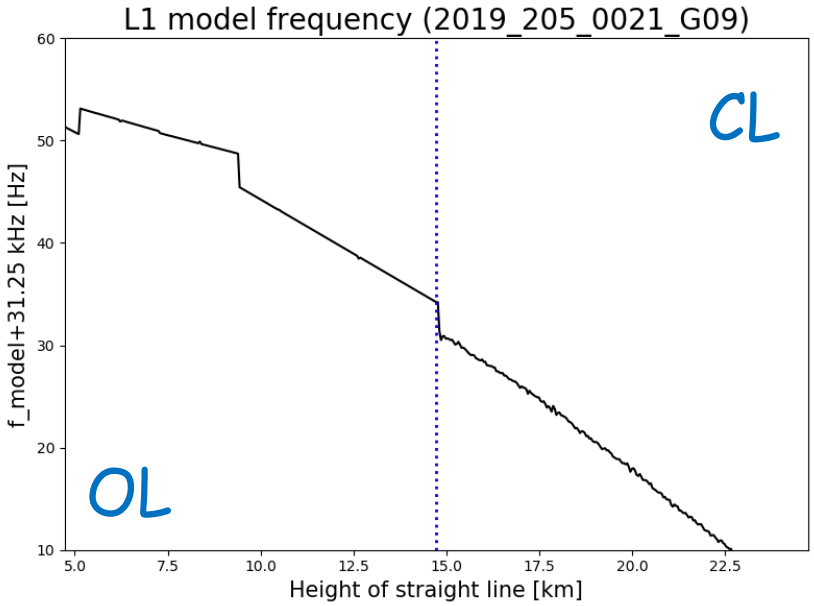

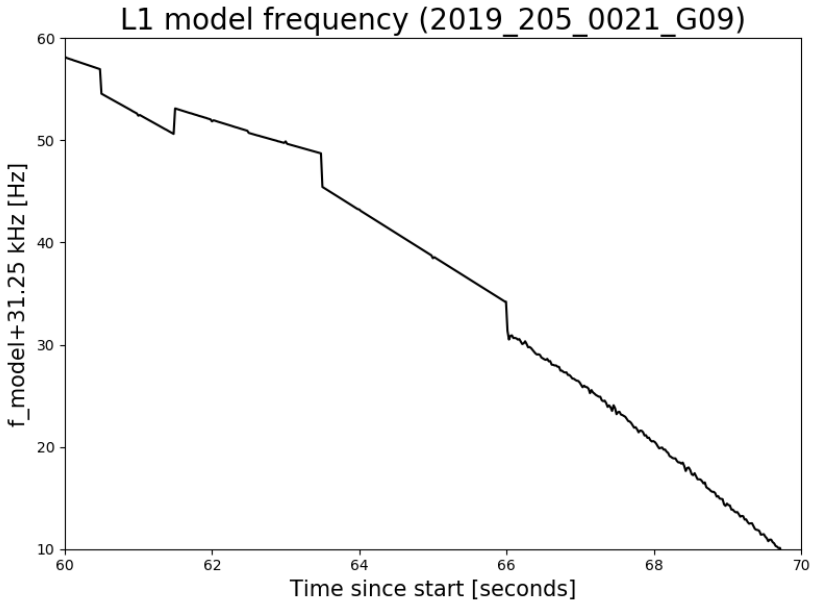

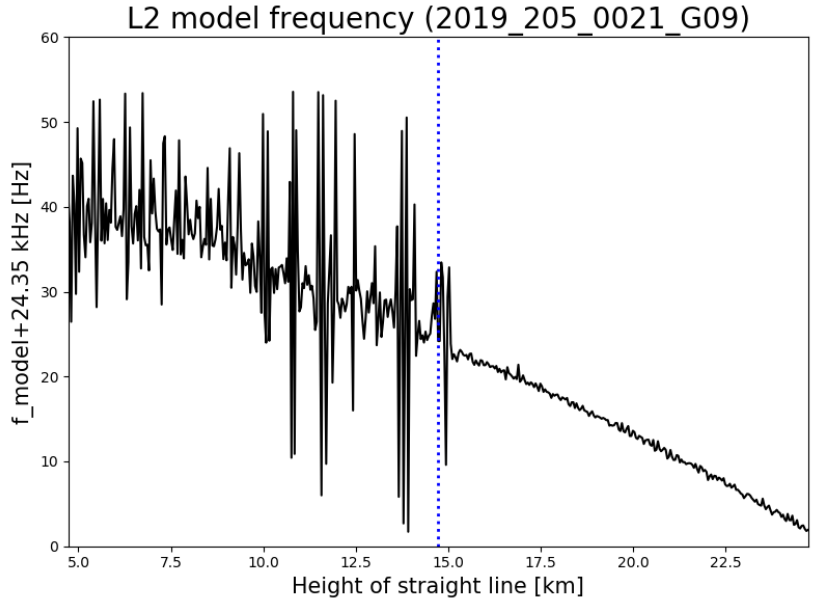

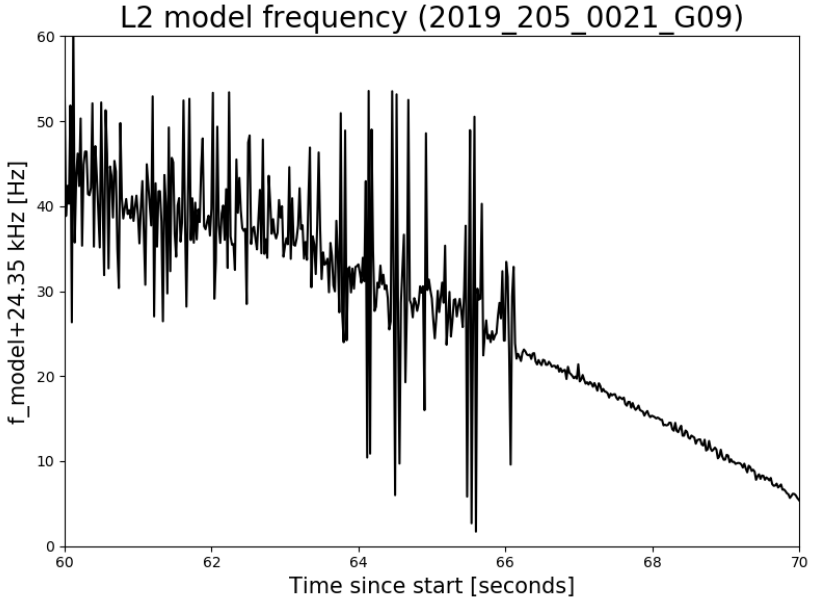

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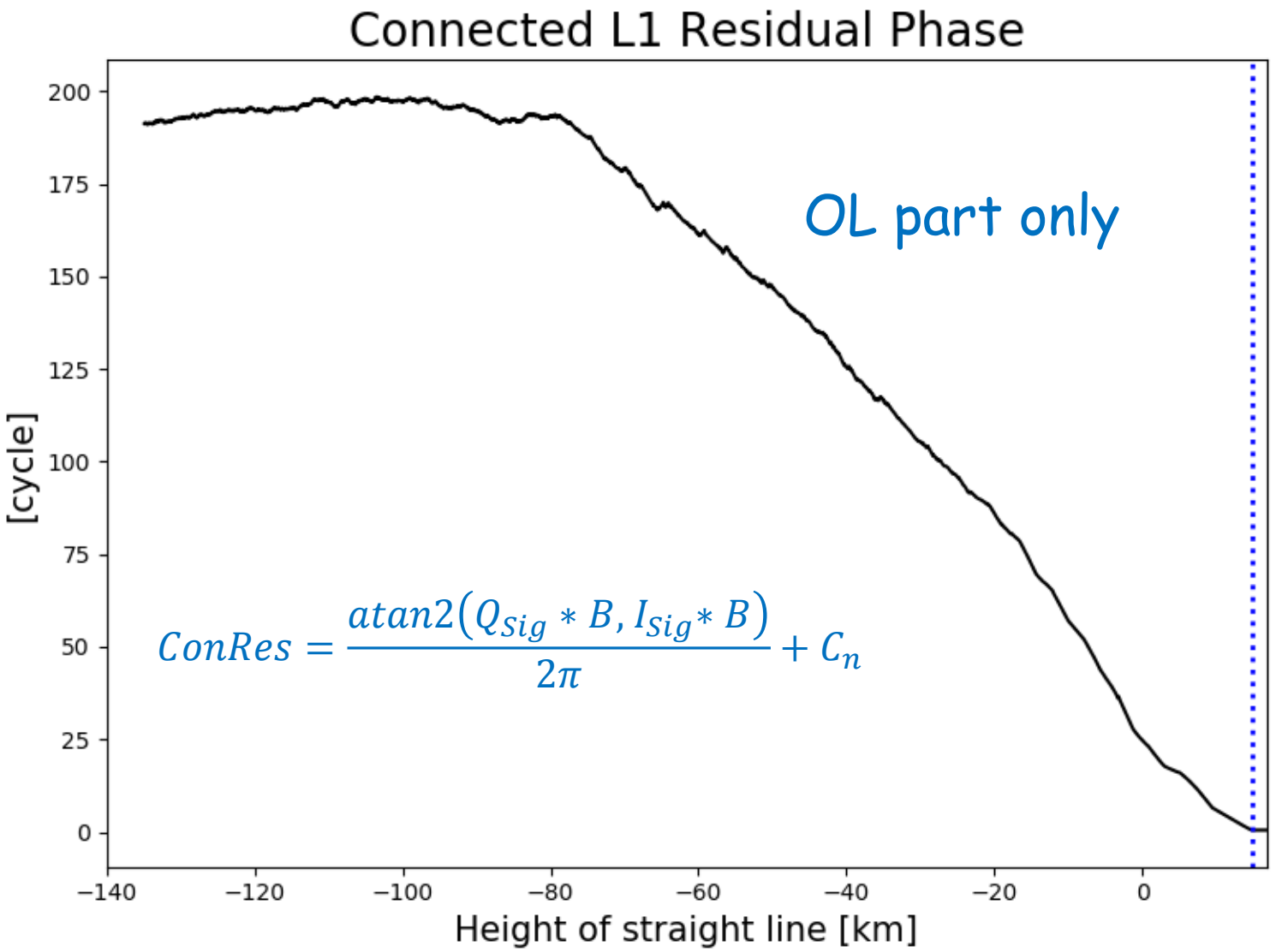

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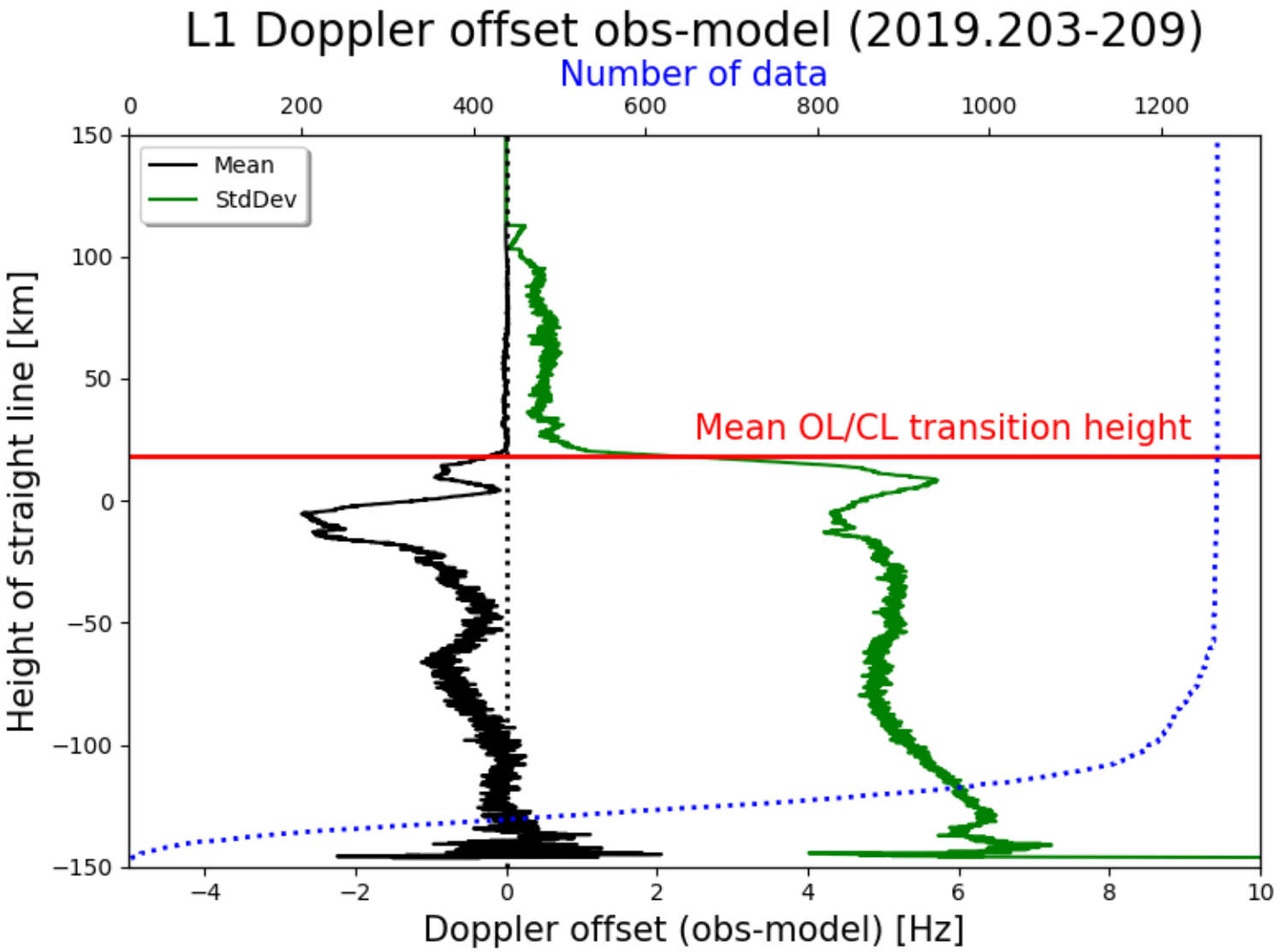

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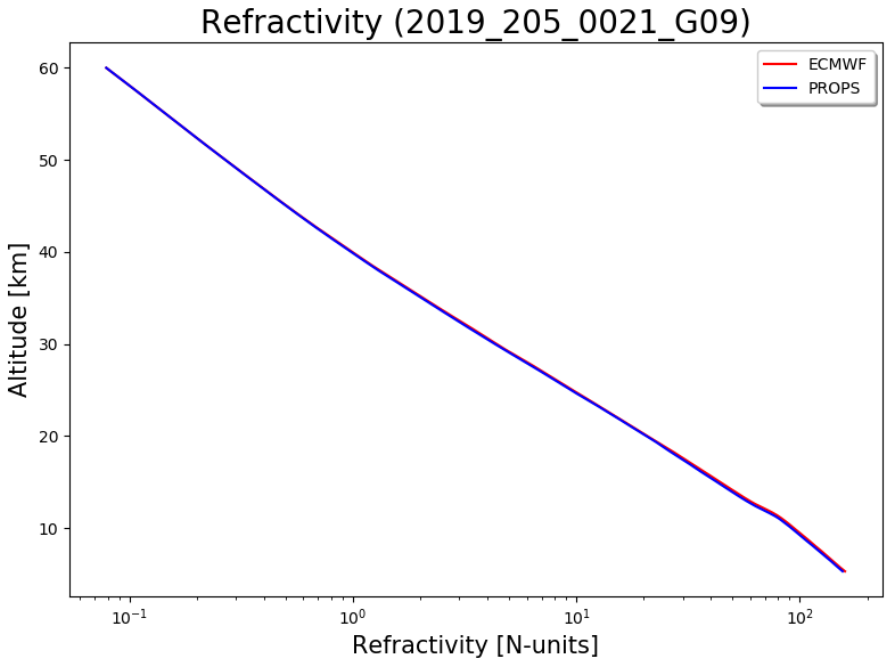
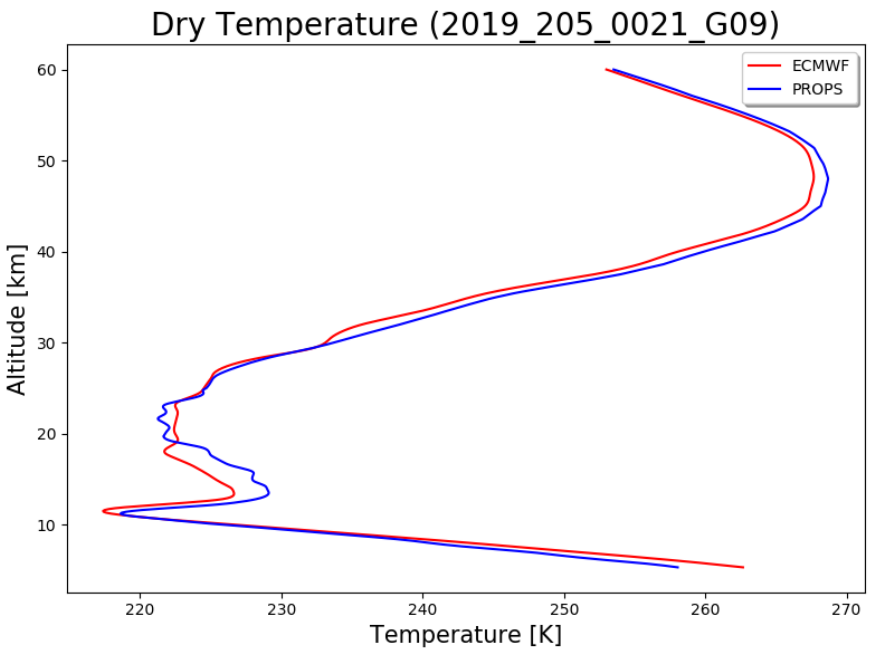




to be continued

GRACE-FO: Next steps

- Command to lower the OL/CL transition to -15 km (as for TSX/TDX)
- Software update
- The new IPU software is expected to fix L2C RO (L2C RO is currently disabled.)
- The SW update will be in November for GF1 and perhaps December for GF2.
- Probably RO on GF2 IPU will be turned on.

Other activities at GFZ: New missions

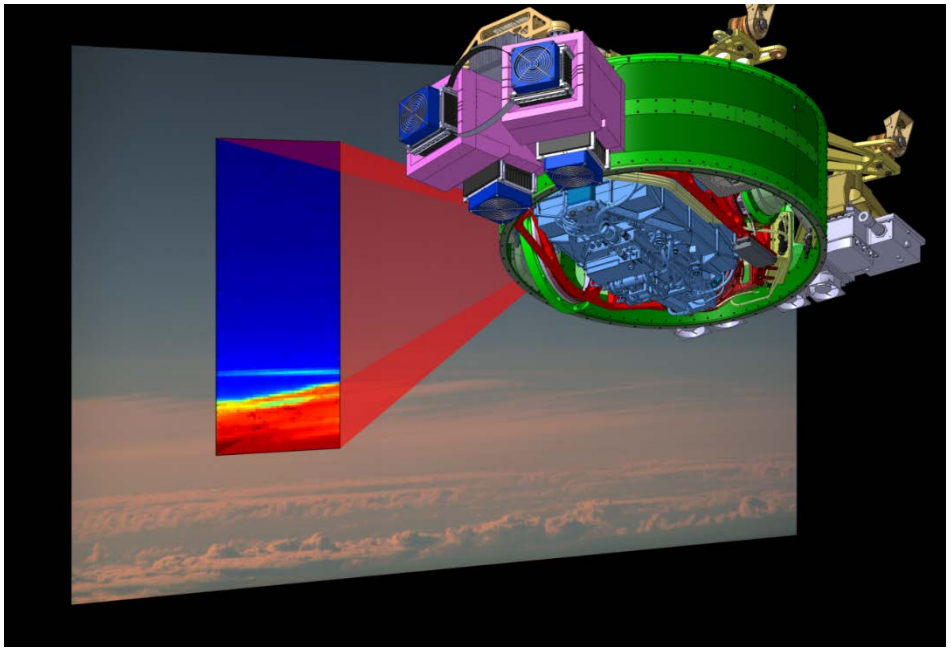
AtmoSat

Highest ranked proposal on the "national roadmap" for big infrastructure projects

Together with Research Center Jülich, KIT Karlsruhe, DLR and other

With RO (TriG)

In the waiting loop



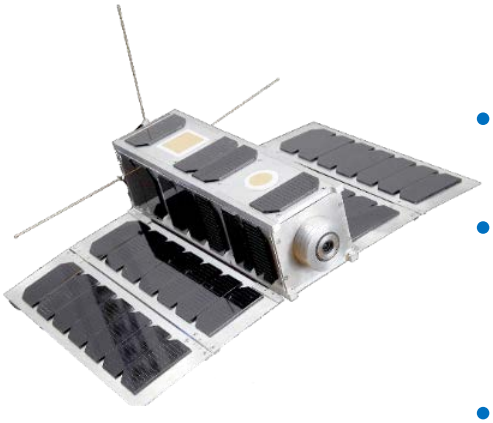
Focus is middle atmosphere (5-100 km)
Observables:
Temperature, H2O, HDO,O3, CH4, N2O, CFC-11, CFC-12, HCFC-12, SF6, HNO3, N2O5, ClONO2, HO2NO2, PAN, C2H6, H2CO, NH3, aerosol and cirrus properties

Resolution: 1 km x 25 km x 50 km (global)

Other activities at GFZ: New missions

PRETTY

Cubesat for precise altimetry using navigation satellites



- Small satellite, cubesat ($10*10*30cm^3$)
- ESA mission, consortium led by RUAG with IEEC and UoO
- GNSS-Reflectometry and Space Weather
- Precise altimetry using grazing geometries
- Unique: Direct correlation of direct and reflected GNSS signals
- Launch expected for 2021

Summary

- GFZ continues with operational RO processing for TSX/TDX
- GRACE-FO RO data available since this summer
  - High OL-CL transition height (compared to TSX/TDX)
    Will be changed soon, expecting big impact
  - Software updates in Nov/Dec with expected improvements (L2C RO availability)
  - Continue with data analysis
- New RO mission(s)

Thank you for your attention!