Processing Batch Length in GNSS Data Analysis: Impact on Daily and Subdaily Earth Rotation Parameters

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EGU General Assembly 2012

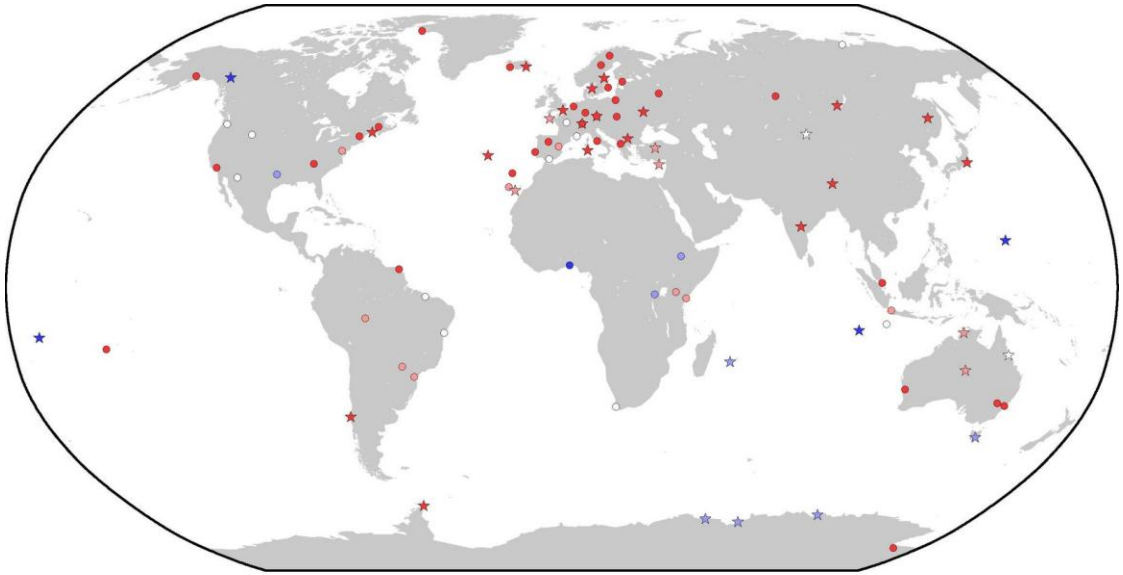
April 24, 2012, Vienna

Introduction and Motivation

- GNSS data analyzed in post-processing mode for high-accuracy applications
  - Data analysis in (usually 24-hour) processing batches
- All GNSS have system-specific periods (revolution periods of satellites)
- Batch length close to GNSS-specific periods may affect solutions
  - Averaging or amplification of errors and unmodeled effects
- What is the impact of the processing batch length on the estimated (polar motion) parameters?

Design and Setup of Study

- 4 years of data analyzed: from 2008–2011
- 92 globally distributed GPS/GLONASS stations
- GPS and GLONASS solutions fully consistent and comparable – in particular concerning station selection



Design and Setup of Study

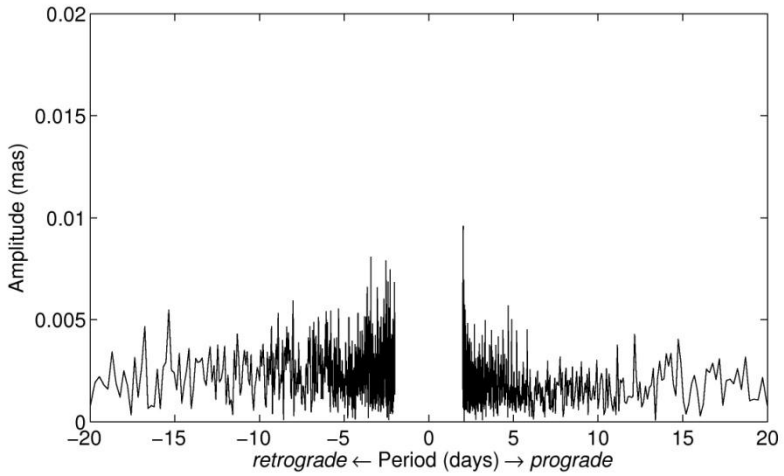
- Batch lengths

ID	adapted to	sid. days	hr:min:sec
GLO	GLONASS	$^{16}/_{17}$	22:32:00
GPS	GPS	$^{17}/_{17}$	23:56:30
DAY	1 day		24:00:00
LNG	–	$^{18}/_{17}$	25:21:00

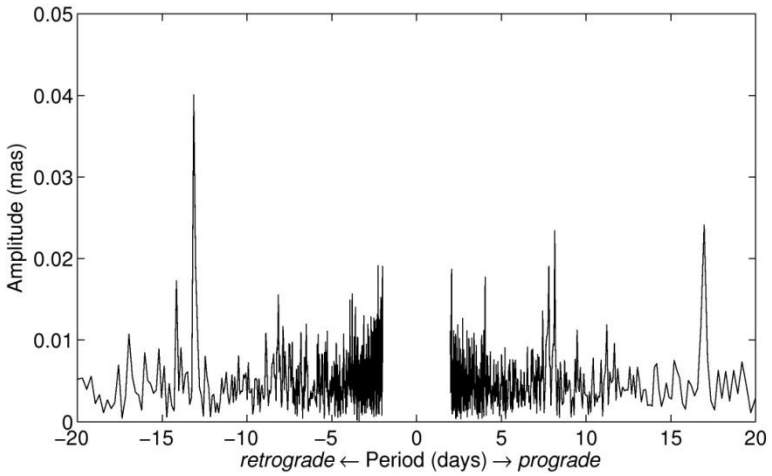
Results: Different Session Length

- Daily X- and Y-estimates of polar motions (relative to C04)

DAY 24:00:00



GPS

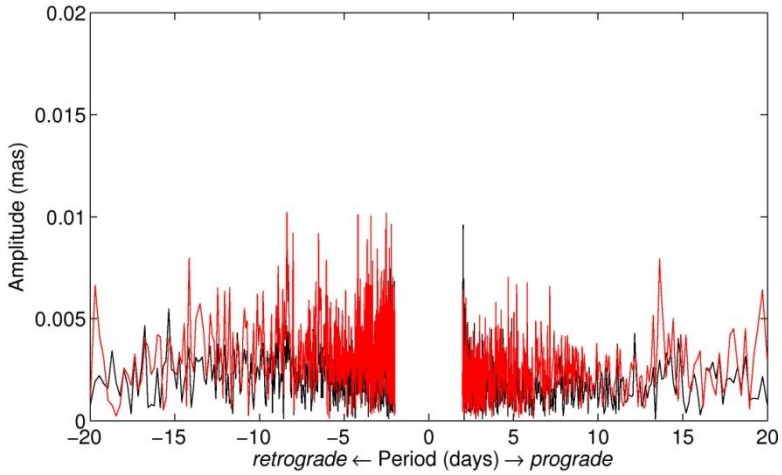


GLONASS

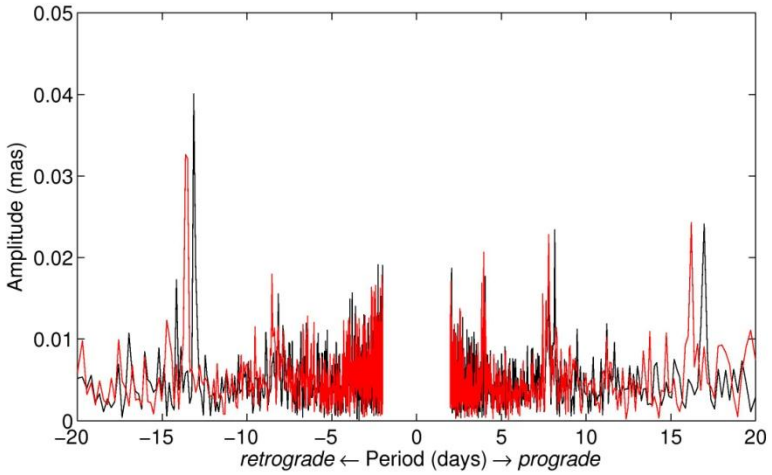
Results: Different Session Length

- Daily X- and Y-estimates of polar motions (relative to C04)

DAY 24:00:00
GPS 23:56:30



GPS

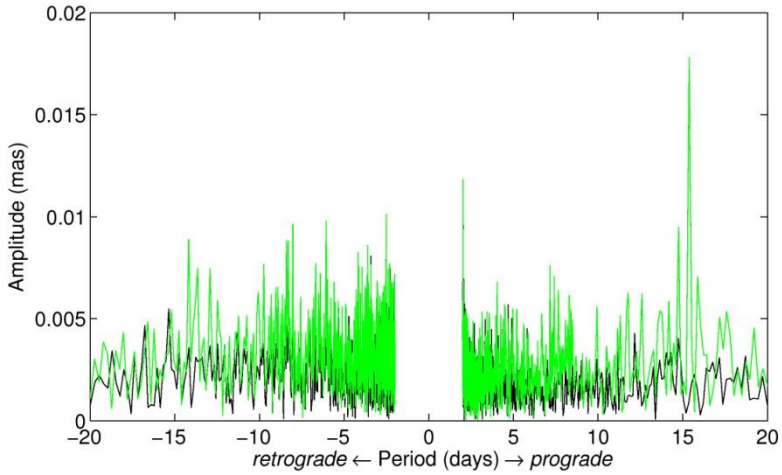


GLONASS

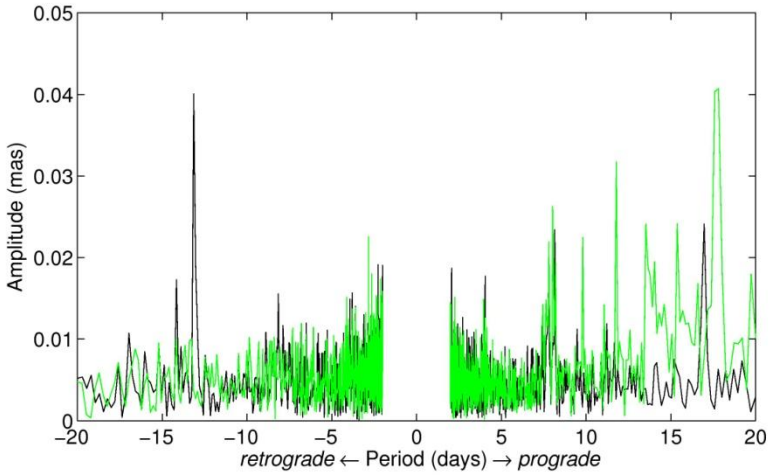
Results: Different Session Length

- Daily X- and Y-estimates of polar motions (relative to C04)

DAY 24:00:00
GLO 22:32:00



GPS

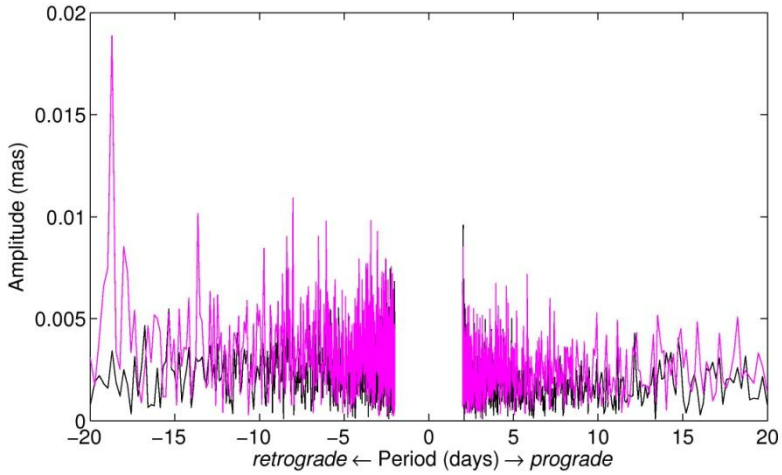


GLONASS

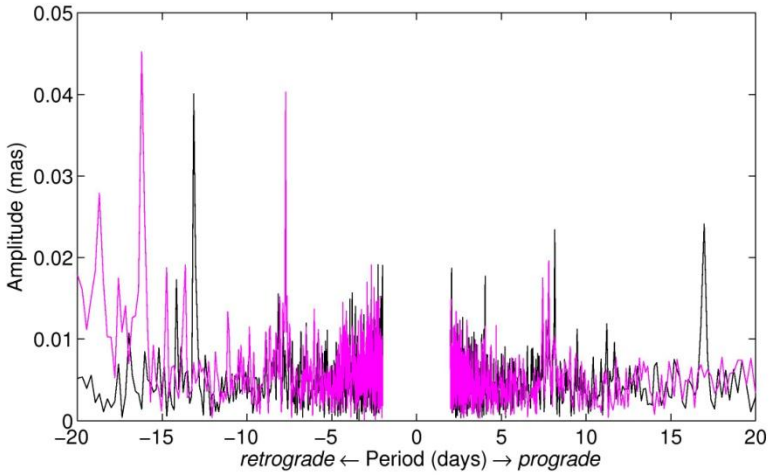
Results: Different Session Length

- Daily X- and Y-estimates of polar motions (relative to C04)

DAY 24:00:00
LNG 25:21:00



GPS



GLONASS

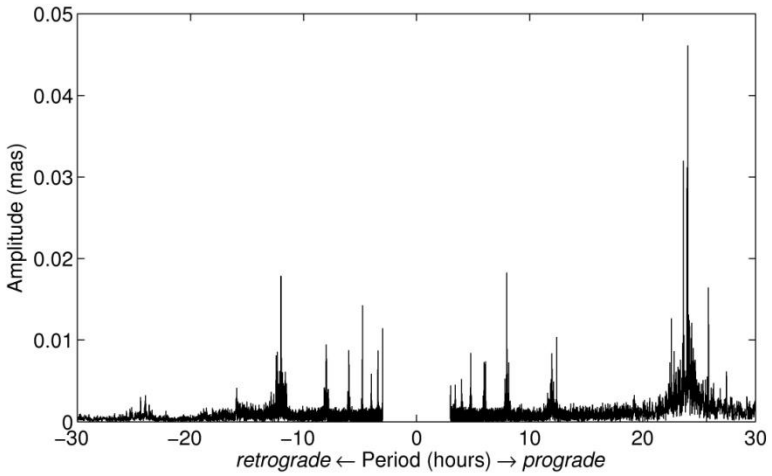
Results: Different Session Length

- Daily X- and Y-estimates of polar motions - **Summary**
- Additional spectral lines show up for both GNSS for the GLO and LNG sessions
  - due to sampling of the revolution period with session length
- Daily (or GPS) session length is the best choice for GPS and GLONASS

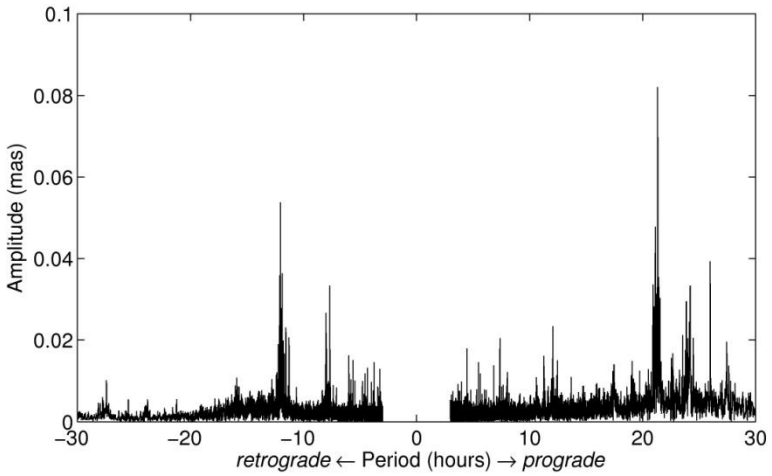
Results: Different Session Length

- Subdaily X- and Y-estimates of polar motions (relative to C04)

DAY 24:00:00



GPS

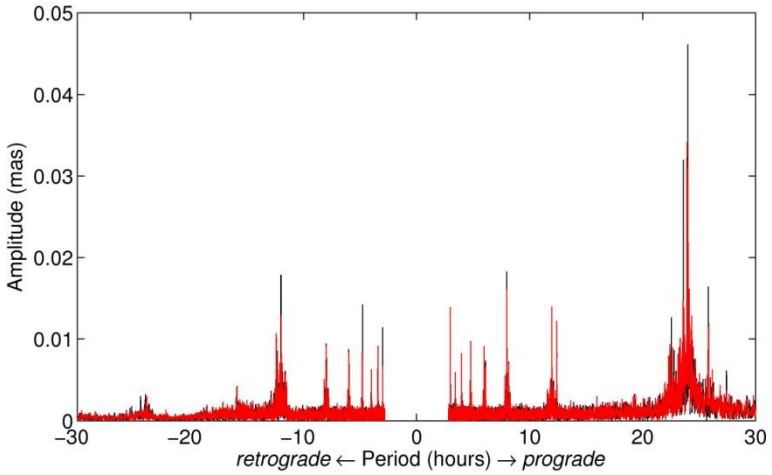


GLONASS

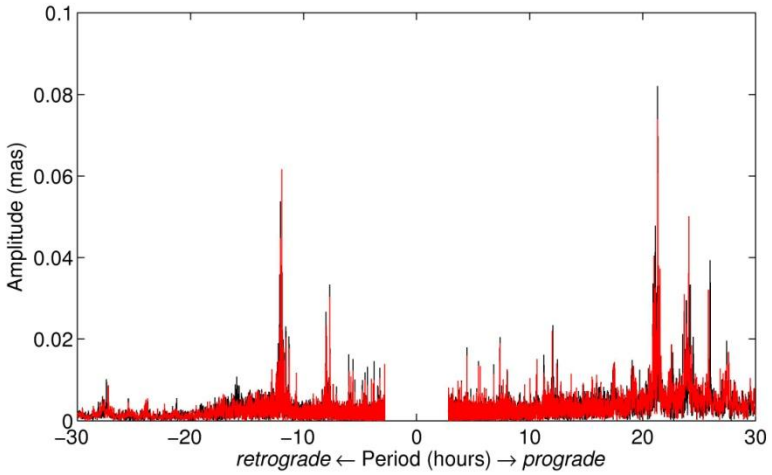
Results: Different Session Length

- Subdaily X- and Y-estimates of polar motions (relative to C04)

DAY 24:00:00
GPS 23:56:30



GPS



GLONASS

Results: Different Session Length

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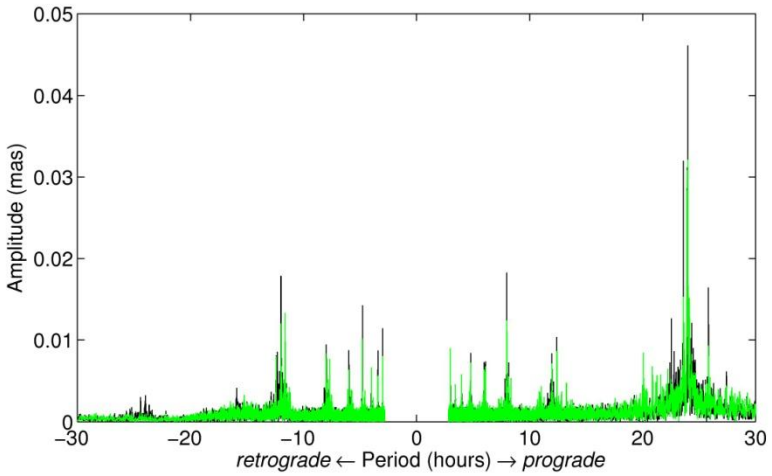
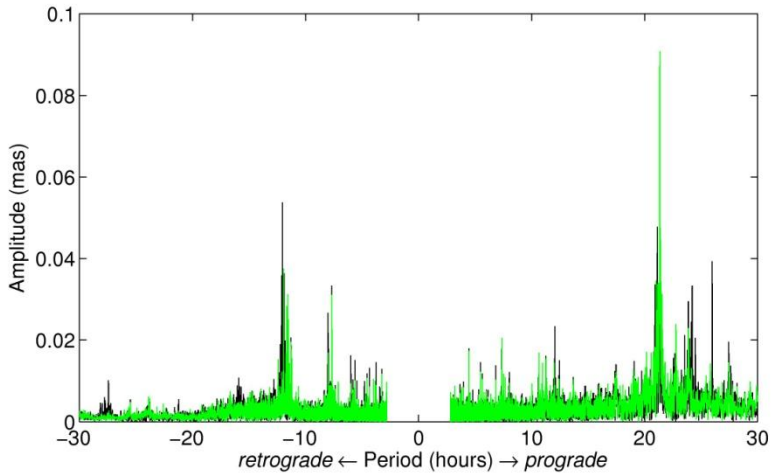
DAY 24:00:00
GLO 22:32:00



GPS

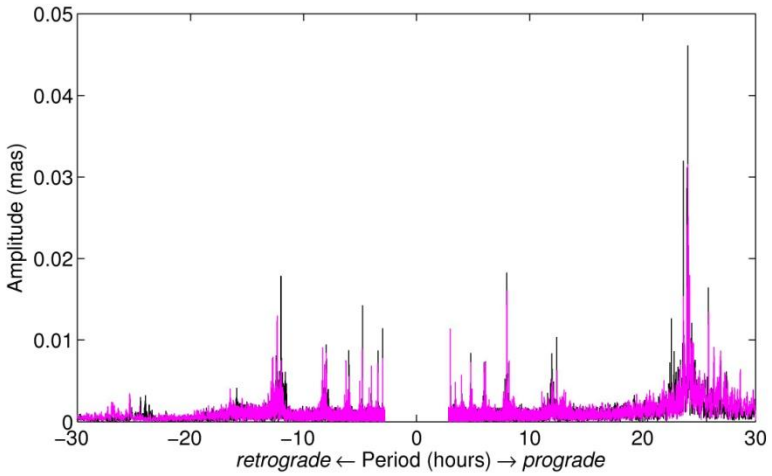


GLONASS

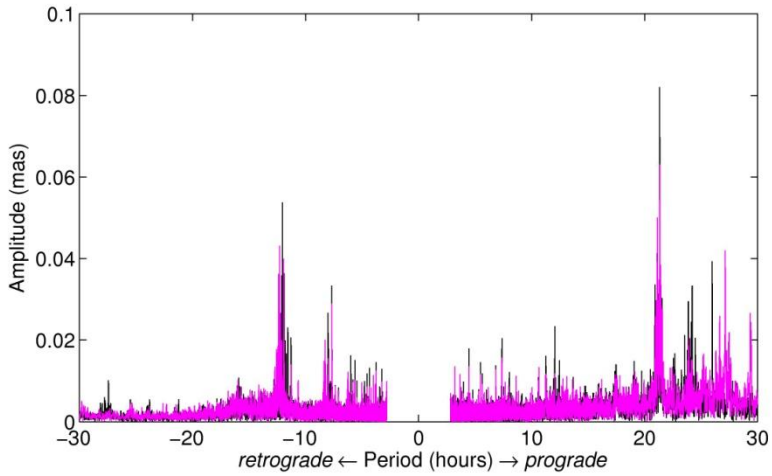
Results: Different Session Length

- Subdaily X- and Y-estimates of polar motions (relative to C04)

DAY 24:00:00
LNG 25:21:00



GPS

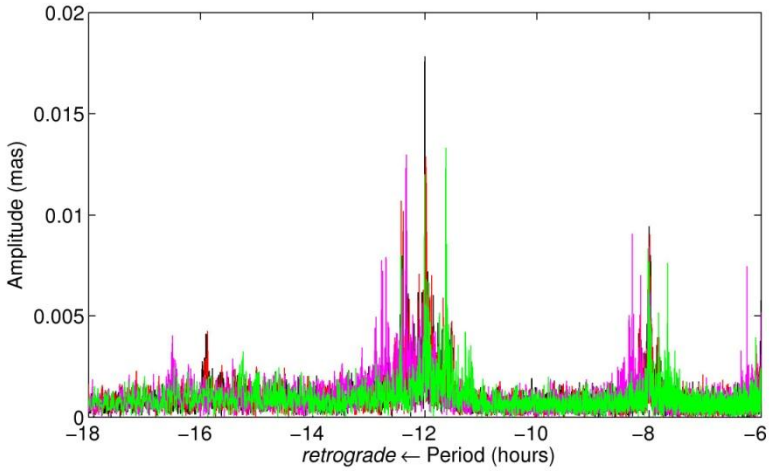


GLONASS

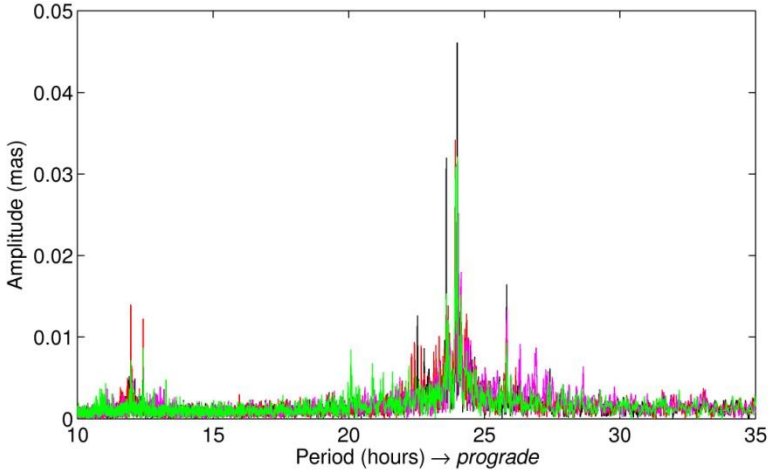
Results: Different Session Length

- Subdaily X- and Y-estimates of polar motions - **GPS**

DAY	24:00:00	GPS	23:56:30
GLO	22:32:00	LNG	25:21:00



retrograde

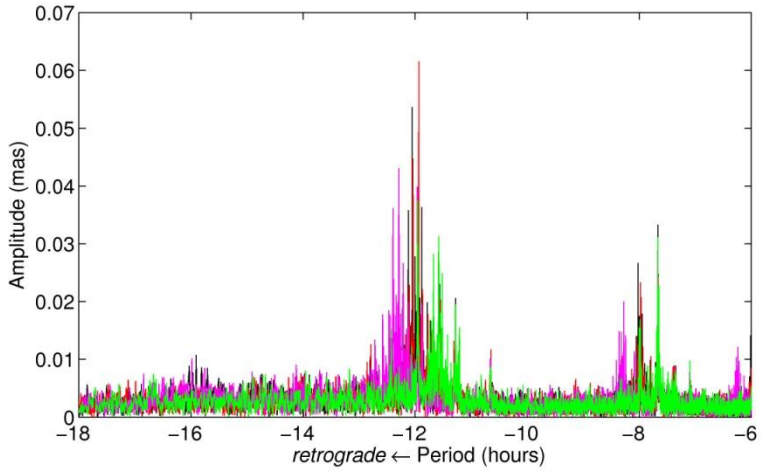


prograde

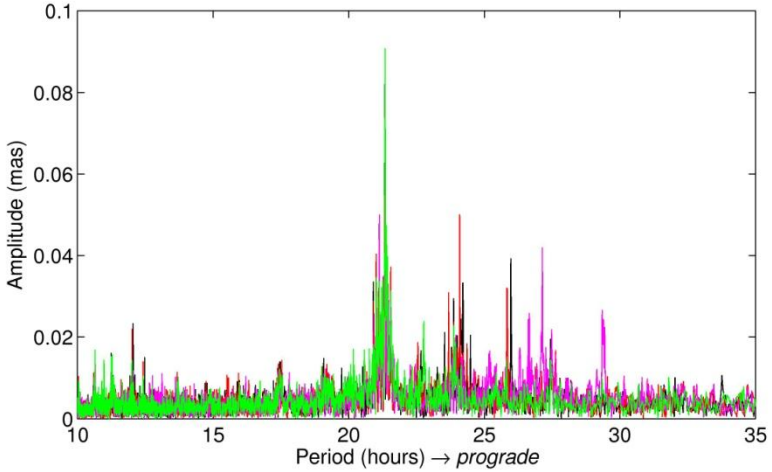
Results: Different Session Length

- Subdaily X- and Y-estimates of polar motions - **GLONASS**

DAY	24:00:00	GPS	23:56:30
GLO	22:32:00	LNG	25:21:00



retrograde



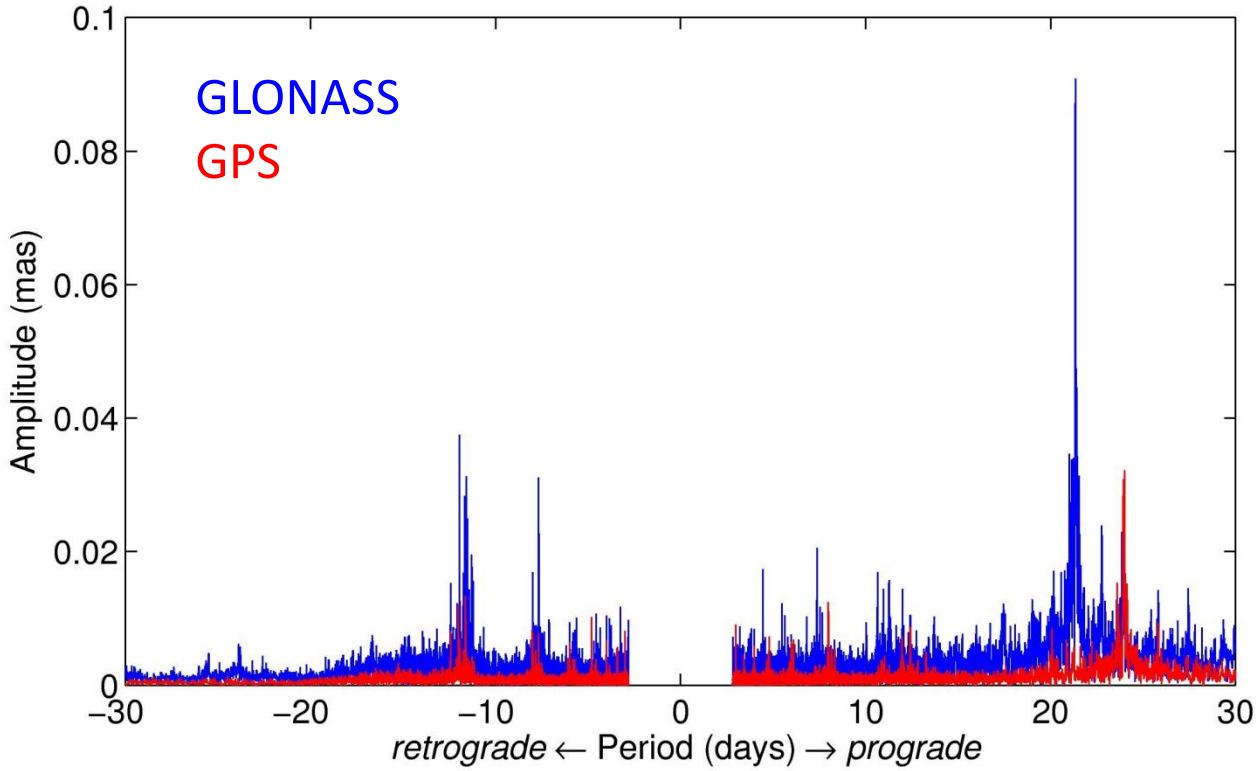
prograde

Results: Different Session Length

- Subdaily X- and Y-estimates of polar motions - **Summary**
- Additional session length-dependent lines show up
- System-specific sessions show the best agreement with C04 for each GNSS

Results: GNSS-Specific Artifacts

- Many spectral lines are different for GPS and GLONASS
- These lines are most likely system-specific artifacts



Results: GNSS-Specific Artifacts

- A constant force perpendicular to orbital plane (W-direction) changes the orientation of the orbital plane

$$\delta i(t) = \frac{W}{n^2 a} \sin u$$

$$\delta \Omega(t) = \frac{W}{n^2 a \sin i} (\cos u - 1)$$

$$\delta u(t) = \frac{W}{n^2 a \tan i} \cos u$$

- The angles *δi*, *δΩ*, and *δu* are are simple trigonometric functions of the argument of latitude *u* and of multiples thereof

Results: GNSS-Specific Artifacts

- Orbit perturbations cause errors in the inertial reference frame (as realized by the satellites)

$$\mathbf{r}(t) = a\ \mathbf{R}_3(-\Omega)\ \mathbf{R}_1(-i)\ \mathbf{R}_3(-u)\ \mathbf{e}_1$$

$$\mathbf{r}'(t) = a\ \mathbf{R}_3(-\Omega-\delta\Omega)\ \mathbf{R}_1(-i-\delta i)\ \mathbf{R}_3(-u-\delta u)\ \mathbf{e}_1$$

$$\begin{aligned}\mathbf{r}'(t) = {} & \mathbf{R}_3(-\delta u\cos i - \delta\Omega) \\ & \mathbf{R}_2(-\delta i\sin\Omega + \delta u\sin i\cos\Omega) \\ & \mathbf{R}_1(-\delta i\cos\Omega - \delta u\sin i\sin\Omega)\ \mathbf{r}(t)\end{aligned}$$

Results: GNSS-Specific Artifacts

- Orbit perturbations cause errors in the inertial reference frame (as realized by the satellites)

$$\mathbf{r}(t) = a\ \mathbf{R}_3(-\Omega)\ \mathbf{R}_1(-i)\ \mathbf{R}_3(-u)\ \mathbf{e}_1$$

$$\mathbf{r}'(t) = a\ \mathbf{R}_3(-\Omega-\delta\Omega)\ \mathbf{R}_1(-i-\delta i)\ \mathbf{R}_3(-u-\delta u)\ \mathbf{e}_1$$

$$\begin{aligned}\mathbf{r}'(t) = \mathbf{R}_3(&-\delta u \cos i - \delta\Omega) \quad \zeta\\ \mathbf{R}_2(&-\delta i \sin\Omega + \delta u \sin i \cos\Omega) \quad \xi\\ \mathbf{R}_1(&-\delta i \cos\Omega - \delta u \sin i \sin\Omega)\ \mathbf{r}(t) \quad \eta\end{aligned}$$

Results: GNSS-Specific Artifacts

- The angles ξ and η contain terms in sin *u* and cos *u* (*u*=*n*·*t*)
- They may be written as a superposition of pro- and retrograde circular motions (with basic frequency: ±*m*·*n*)

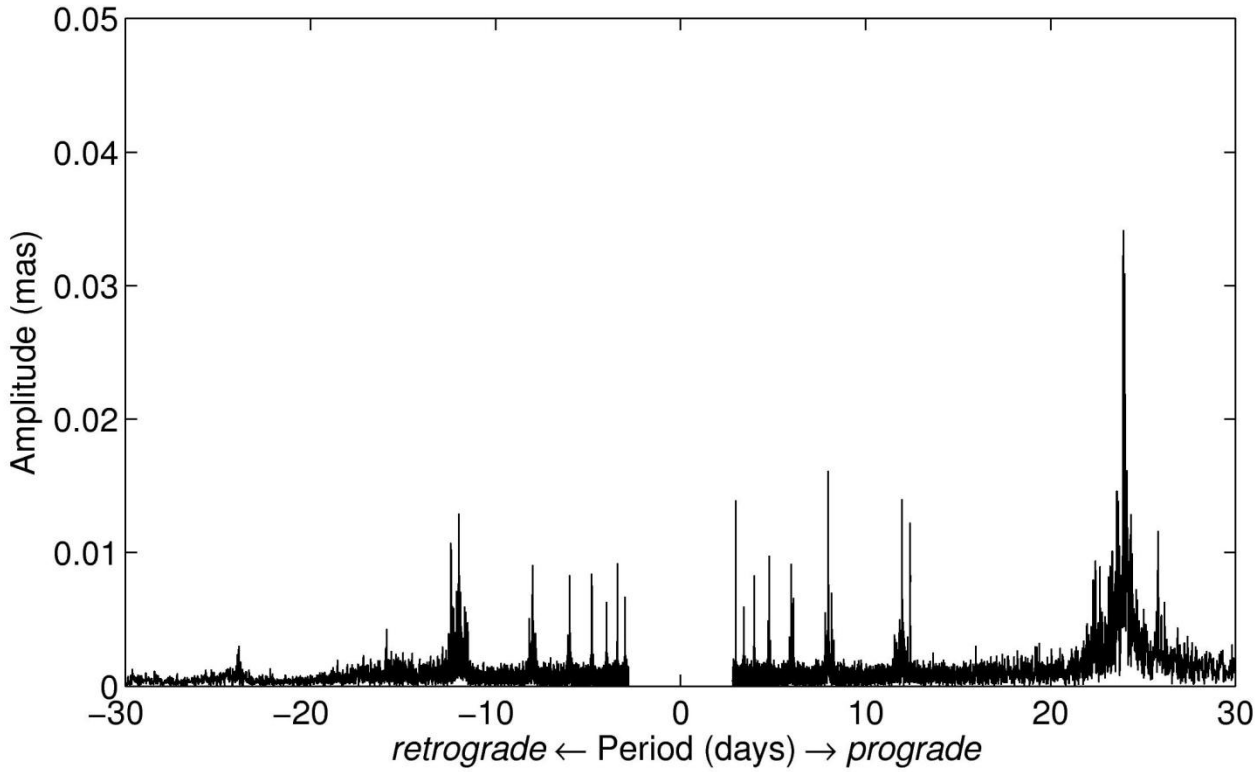
$$\xi = \rho \cos(mu + \tilde{\phi})$$
$$\eta = \rho \sin(mu + \tilde{\phi})$$

- These terms translate into spectral lines in polar motion

$$x = \rho \cos(\Theta + mu + \tilde{\phi})$$
$$y = \rho \sin(\Theta + mu + \tilde{\phi})$$

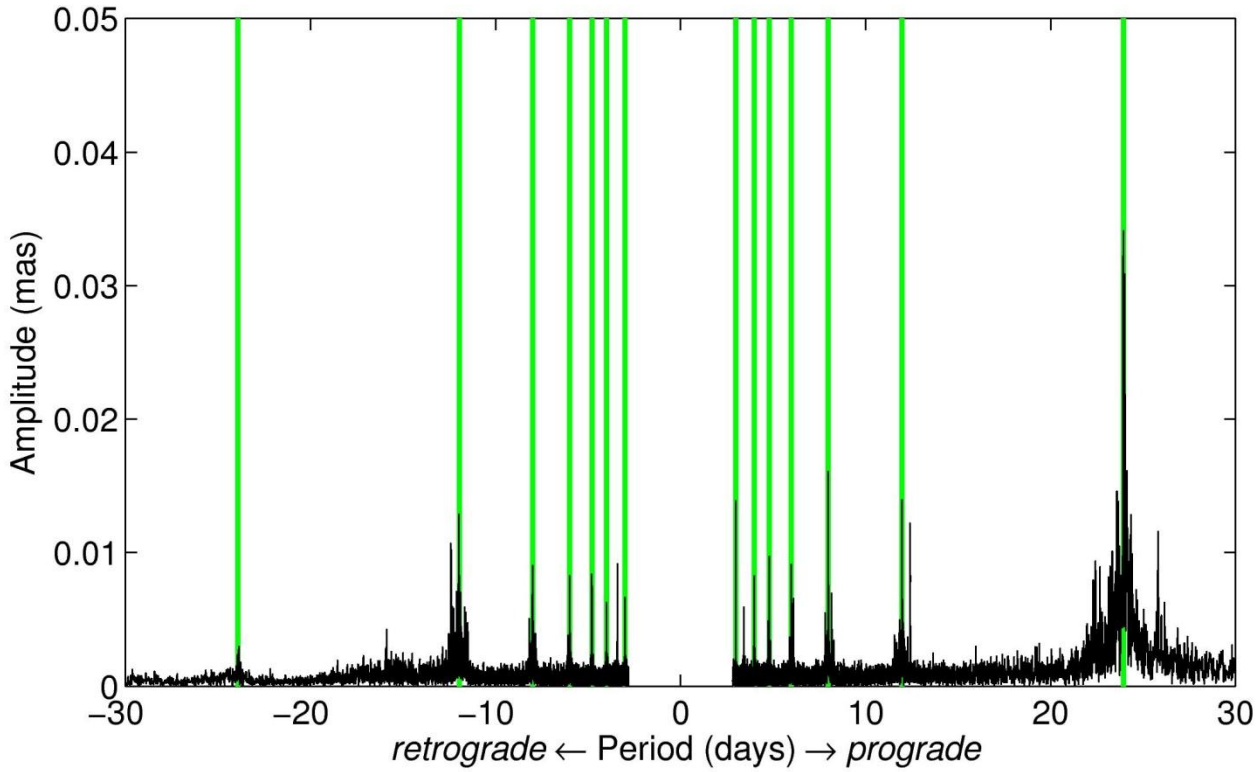
Results: GNSS-Specific Artifacts

- GPS, orbital period: 11:58 h (0.5 sidereal days)



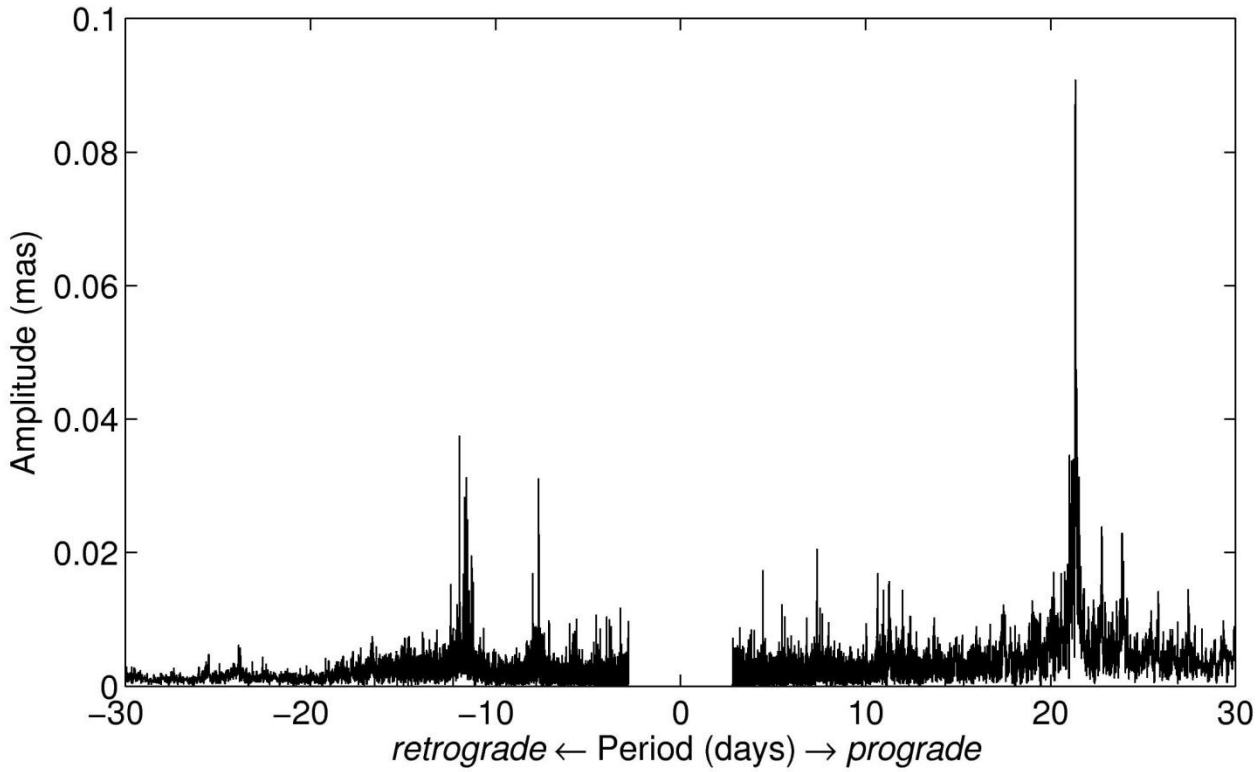
Results: GNSS-Specific Artifacts

- GPS, orbital period: 11:58 h (0.5 sidereal days)



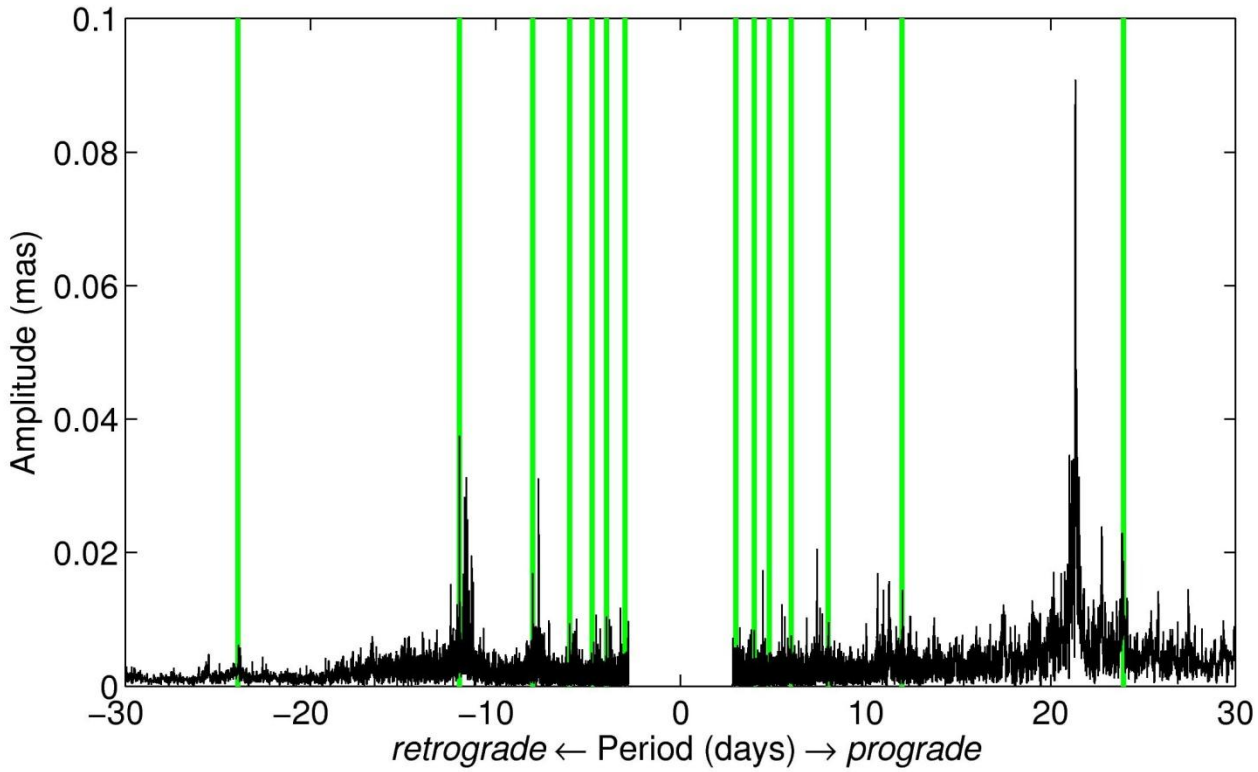
Results: GNSS-Specific Artifacts

- GLONASS, orbital period: 11:16 h



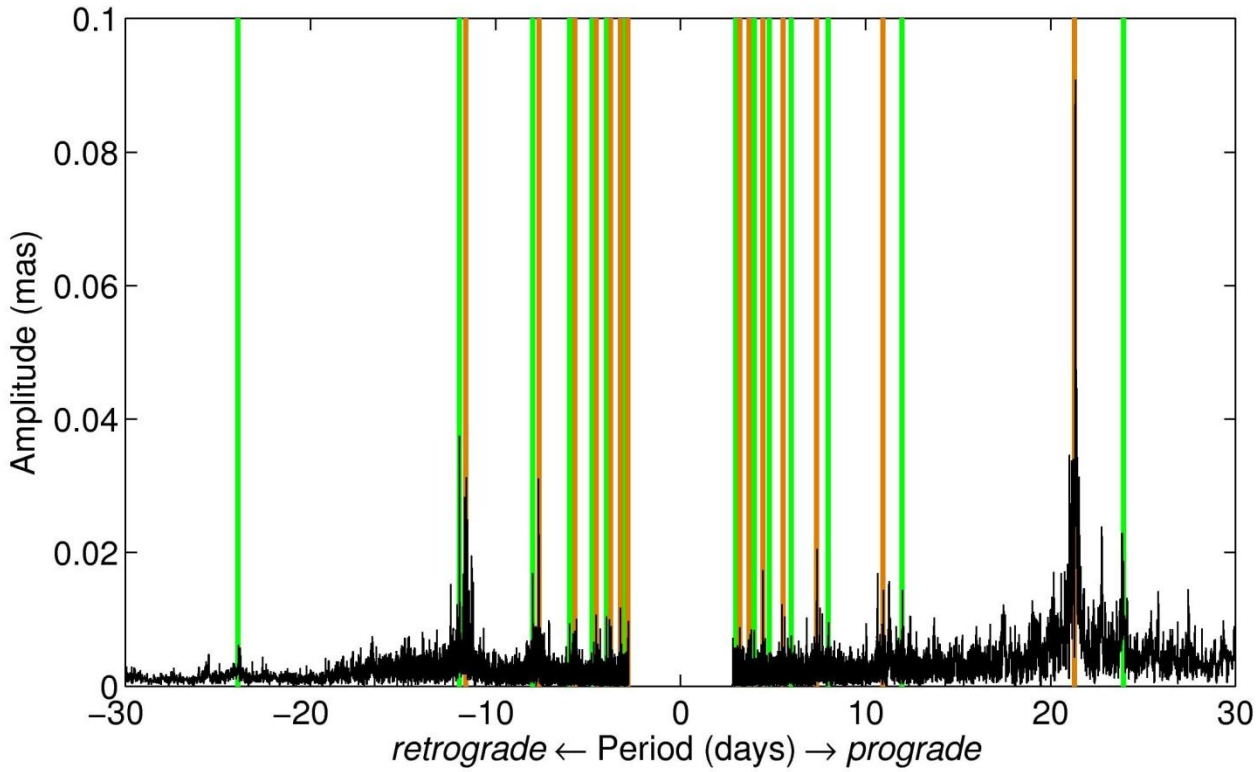
Results: GNSS-Specific Artifacts

- GLONASS, orbital period: 11:16 h



Results: GNSS-Specific Artifacts

- GLONASS, orbital period: 11:16 h



Summary

- The session length has an impact on the results.
  - The effect is not as serious as expected.
  - 24-hour session length is a good choice for the time being.
- Spurious GNSS-specific spectral lines can be explained by perturbation theory.
  - The lines are independent of session length!
  - The lines are harmonics of a sidereal day for GPS.
  - For all other systems with $n \neq 2\omega$ there will be two basic periods, namely the sidereal day and the revolution period.
  - → Such lines will appear in the spectra of Galileo subdaily results as well.