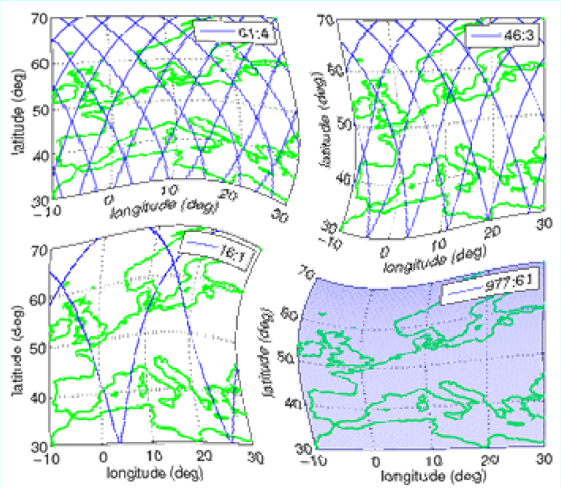
Some aspects of the orbit selection for the measurement phases of GOCE



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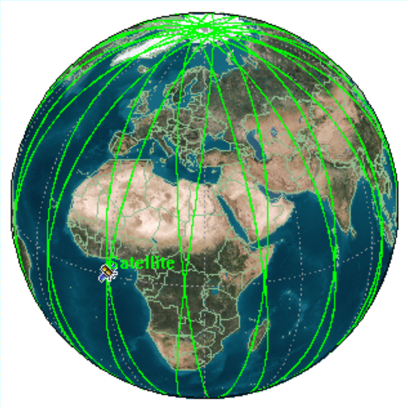
Some aspects of the orbit selection for the measurement phases of GOCE

Outline of the presentation

- Repeat orbits and gravity field modelling

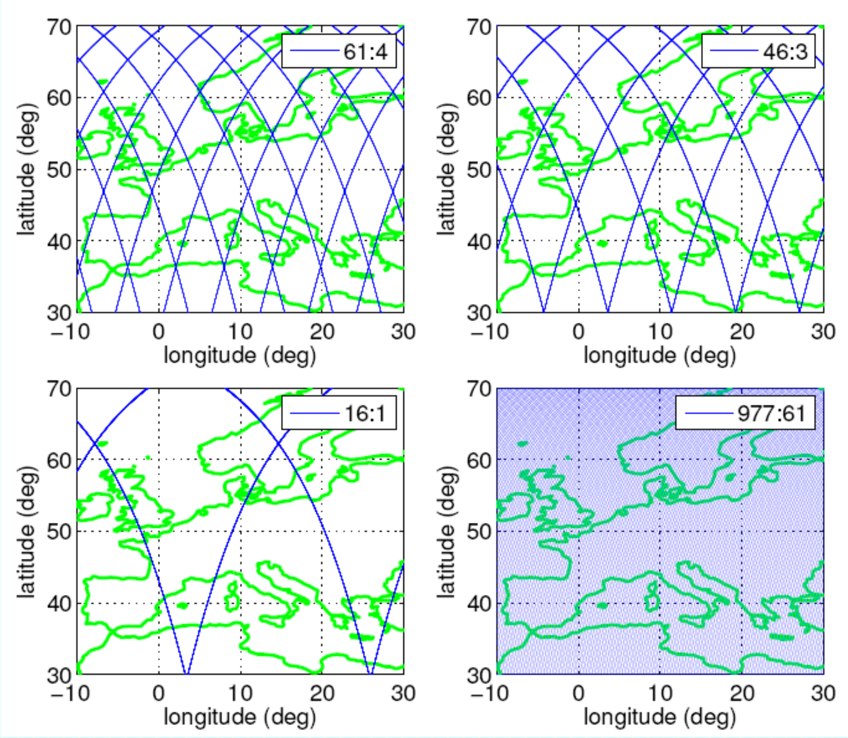
- GOCE and repeat orbits
  - Subcycles
  - Temporal evolution
  - Small variations in altitude
  - Regularity of Earth coverage
  - Planned 145-day repeat orbit

Orbital resonances



Orbital resonance **R:D** takes place, if:

- Groundtracks are exactly the same after **R** nodal revolutions and **D** nodal days
- Equivalent names: repeat orbit, resonant orbit

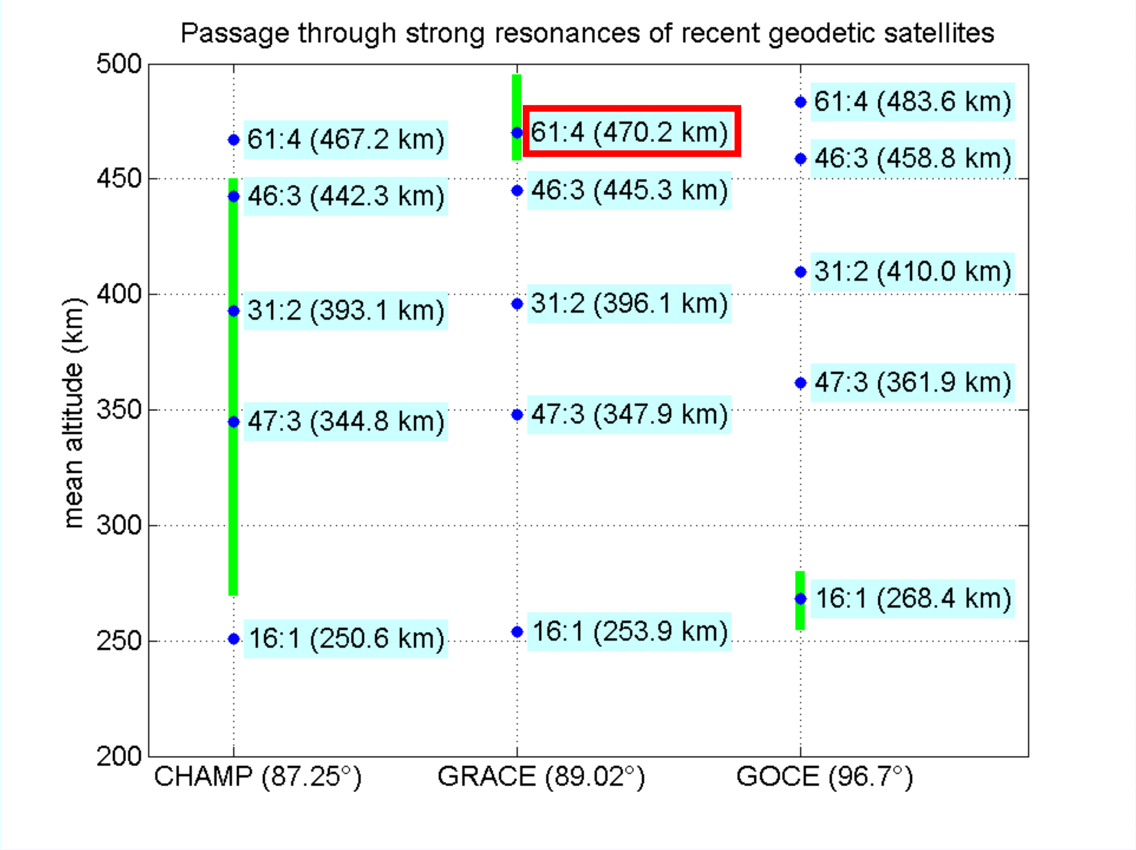


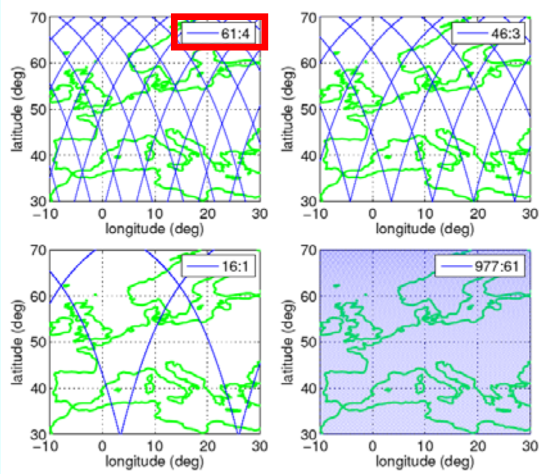
- Modelling of gravity field
  - ➢ Dense enough grid of groundtracks
  - ➢ Rule of thumb (from Nyquist theorem): $\mathbf{n_{max} < R/2}$

  n_{max} maximum degree/order

Orbital resonances and quality of gravity field models

- CHAMP: 46/3, 31/2, 47/3
- GRACE: 61/4
  - Worse quality of monthly gravity solutions in Aug/Sep 2004
- GOCE: 16/1
  - Avoiding gradiometer measurements near the 16/1 repeat orbit

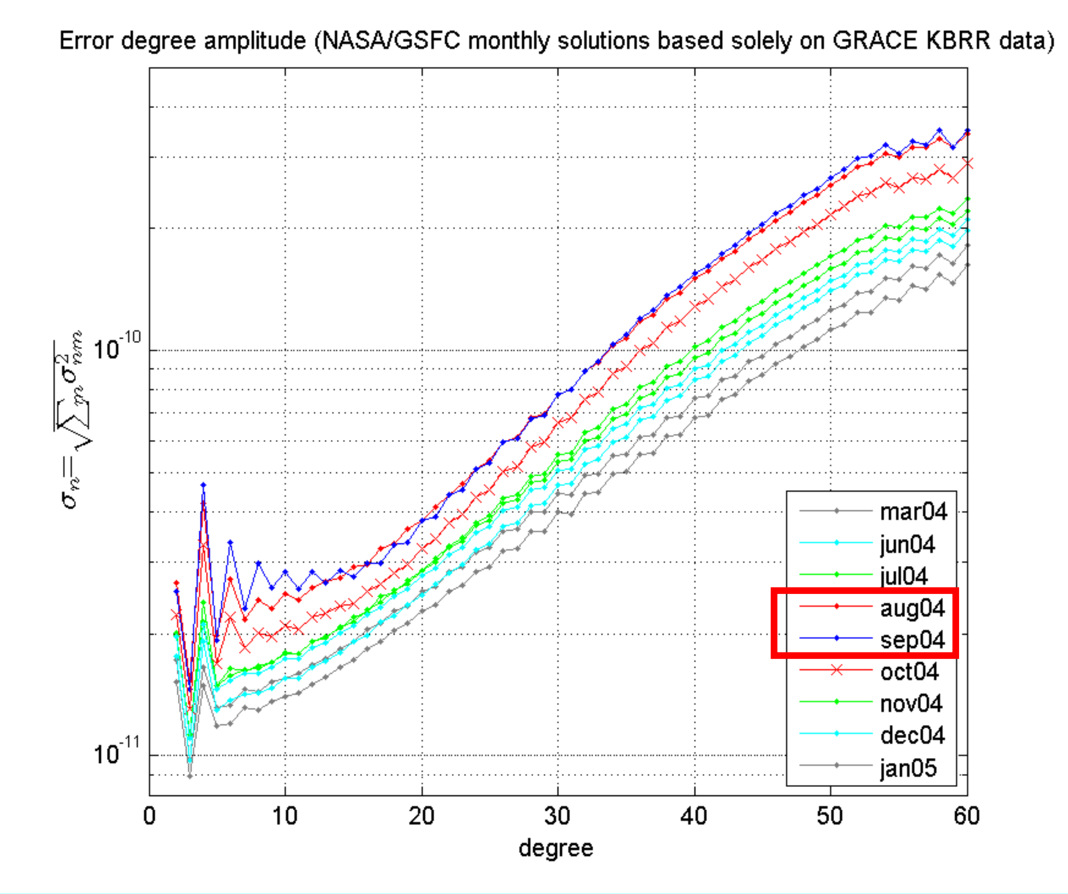


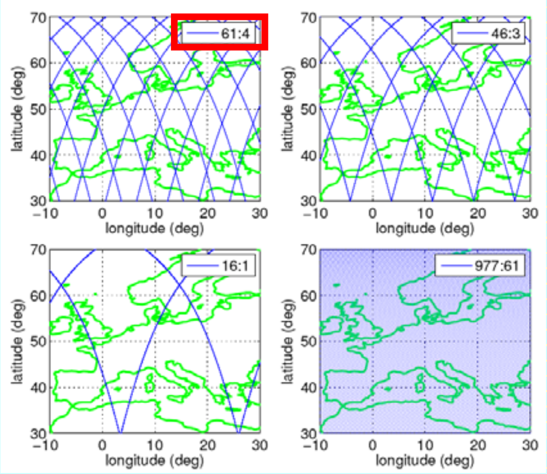


Example – passage of GRACE through 61:4 resonance

- August–September 2004

  → larger degree error in gravity monthlies





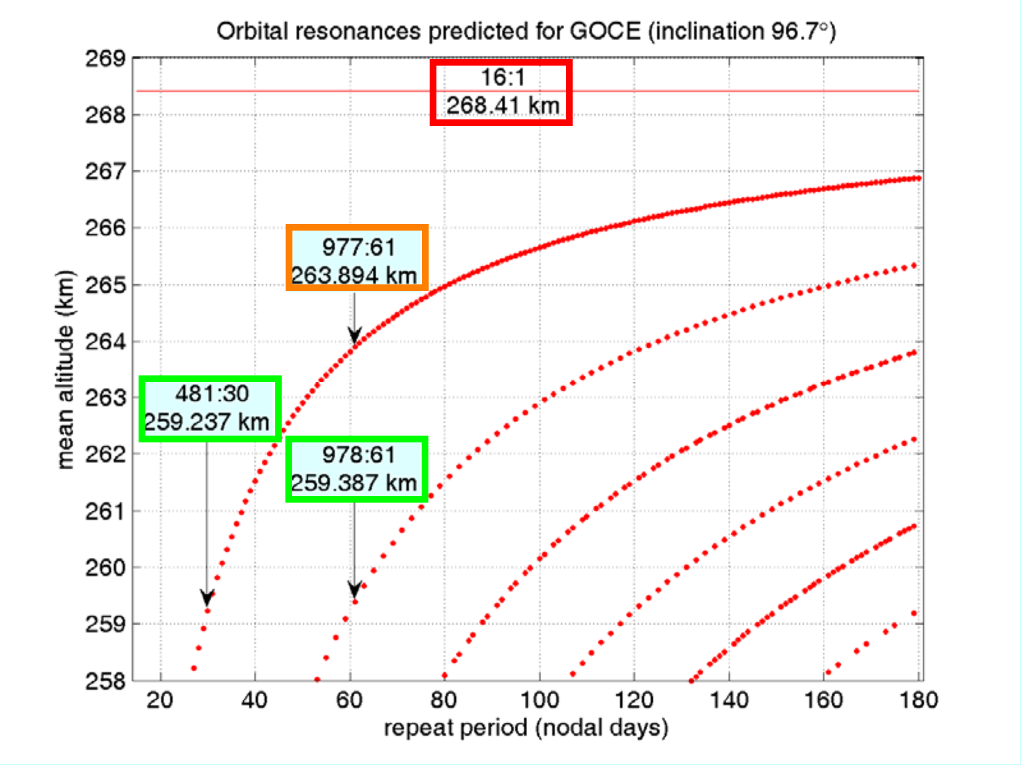
Global gravity field models from GOCE and resonances

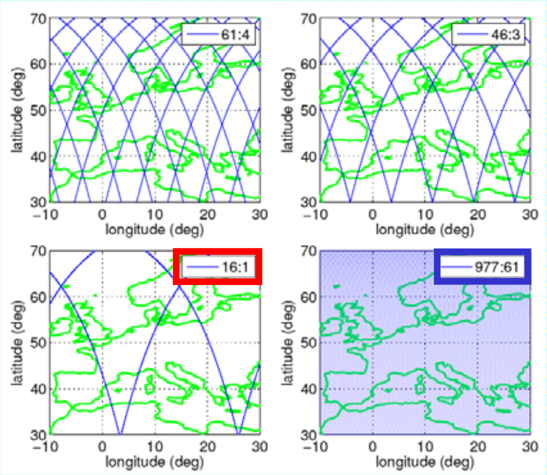
- Resolution of 100 km → minimum repeat period of 2 months
- Altitude as low as possible – limited by performance of ion thruster

Strong **16:1 resonance** must be avoided for the measurement phases

We studied two candidate 61-day orbits providing **dense enough** sampling:

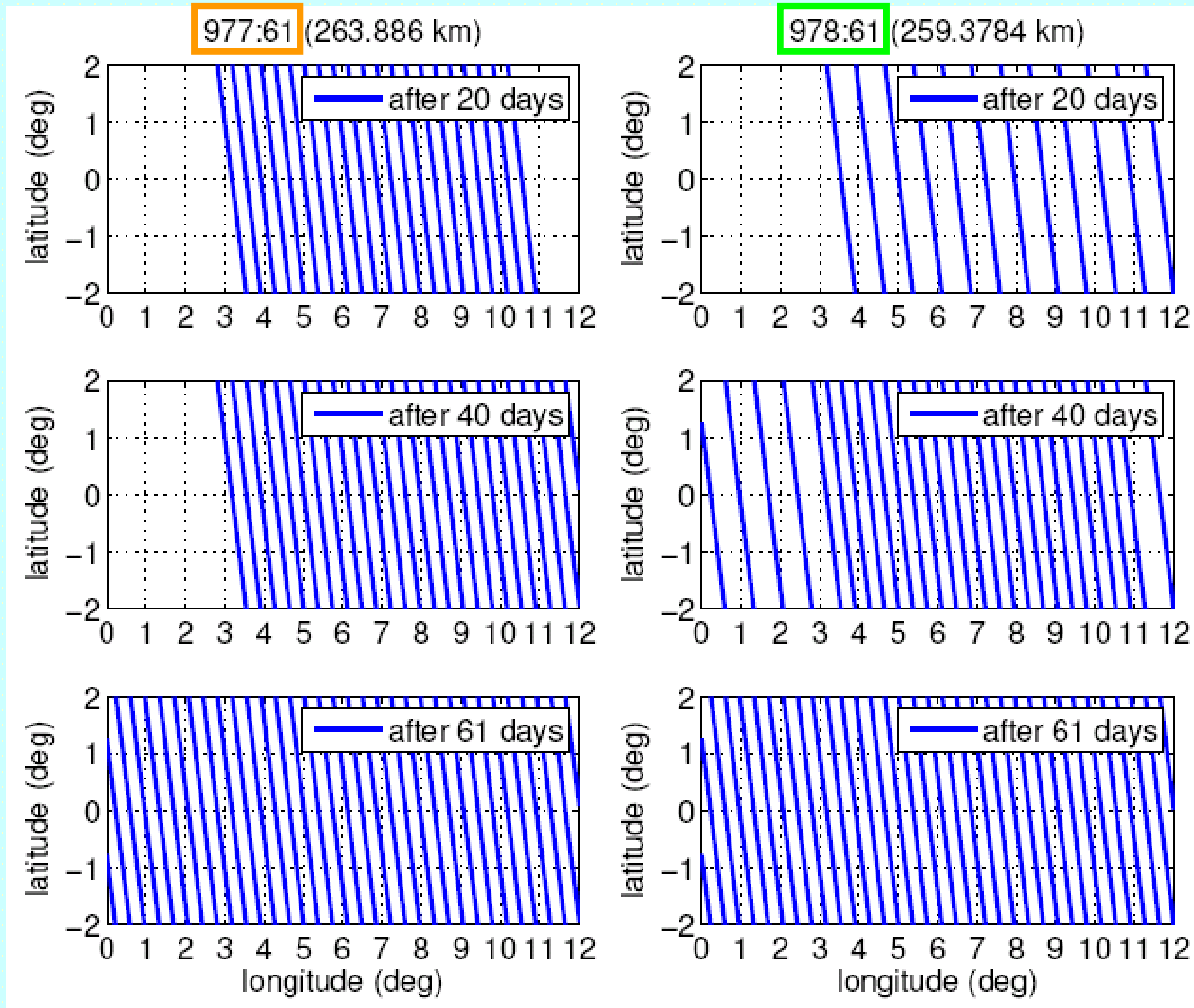
- higher orbit with **no subcycles**
- lower orbit with **30-day subcycle**

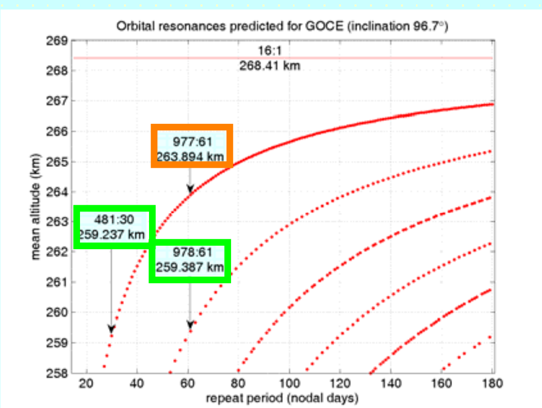




Temporal evolution of an orbit – with/without a subcycle

- Repeat orbit with **no subcycles** → gradually filling up two large equatorial gaps
- Repeat orbit with a **subcycle** → groundtracks laid down in two (or more) almost homogeneous grids





Small variations in altitude of repeat orbits

Exact **61-day repeat orbit**

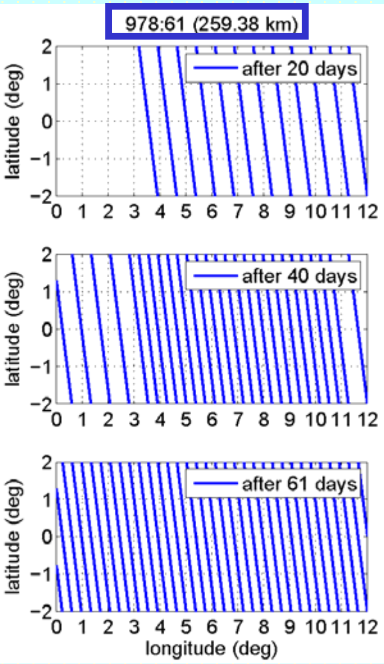
- mean altitude 259.38 km
- one peak in histogram

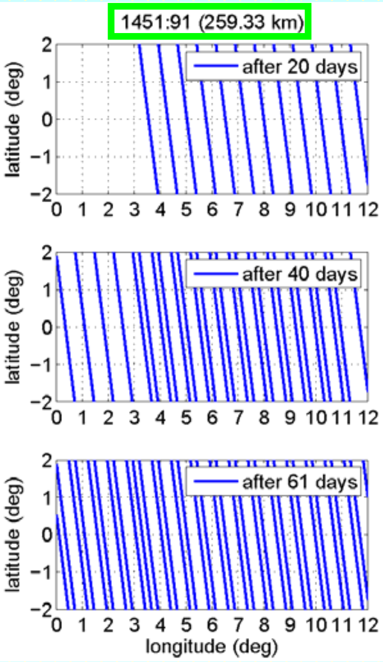
Height lower by 50 m

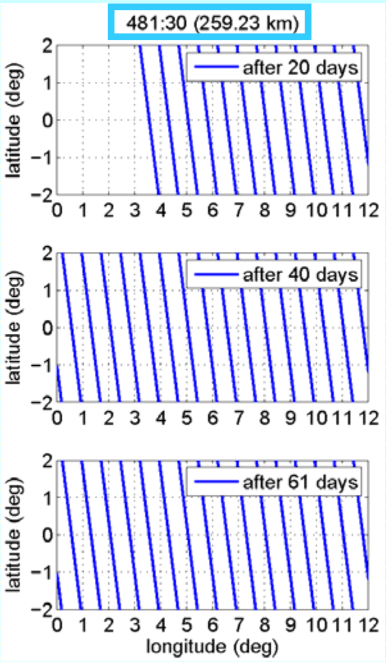
- grid not regular after 61 days
- in fact, **91**-day repeat

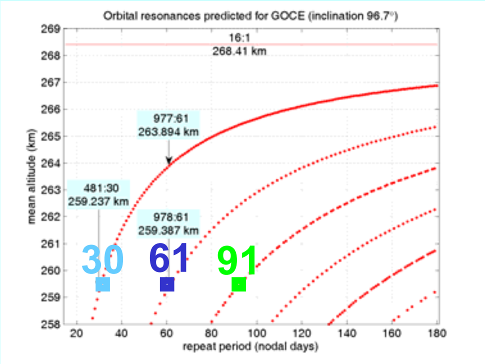
30-day subcycle

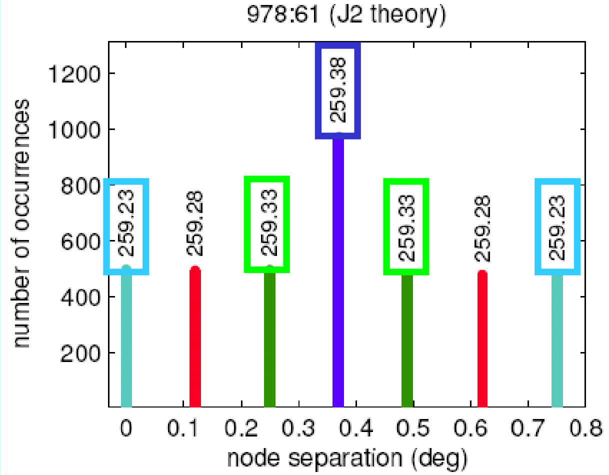
- mean height **lower by 150 m**
- inacceptable for GOCE







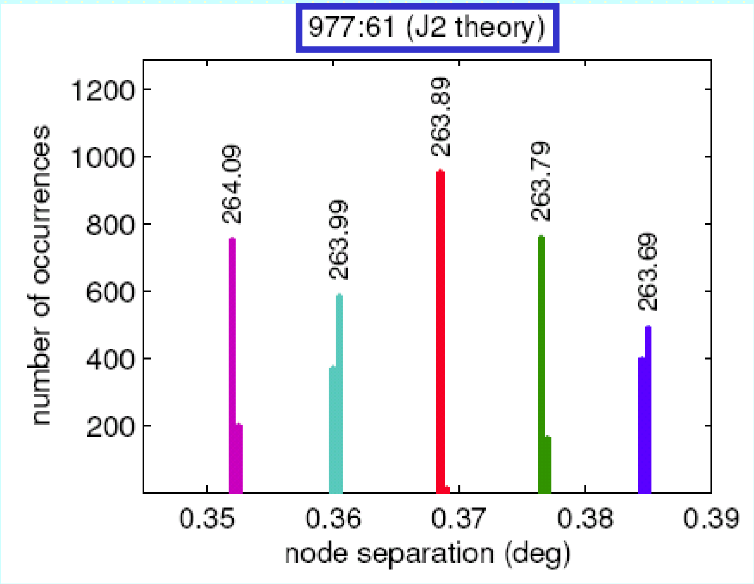


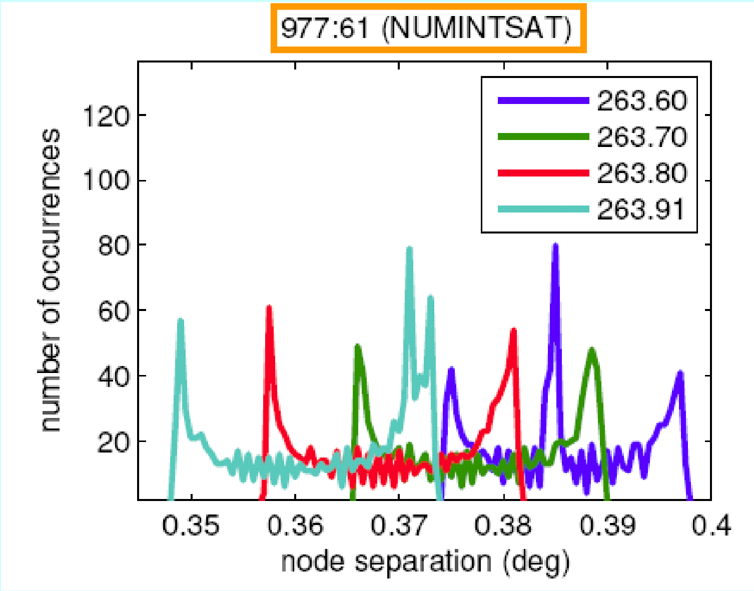


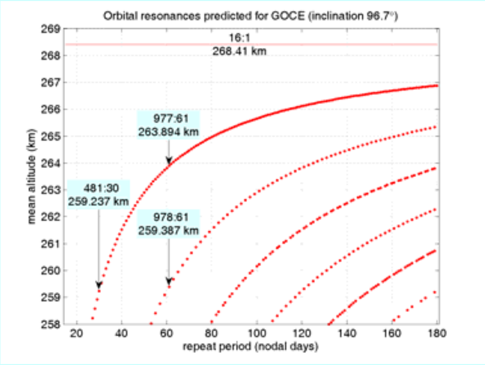
Analytical vs. numerical modelling

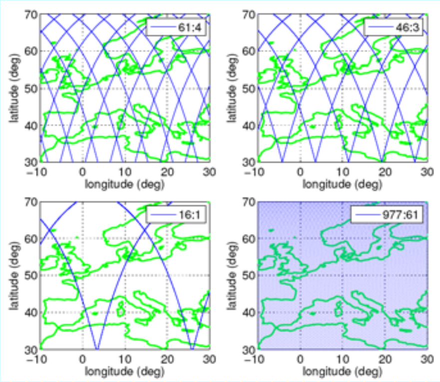
- So far, graphs based on simple theory with **only** the **zonal term J2** (flattening of Earth)

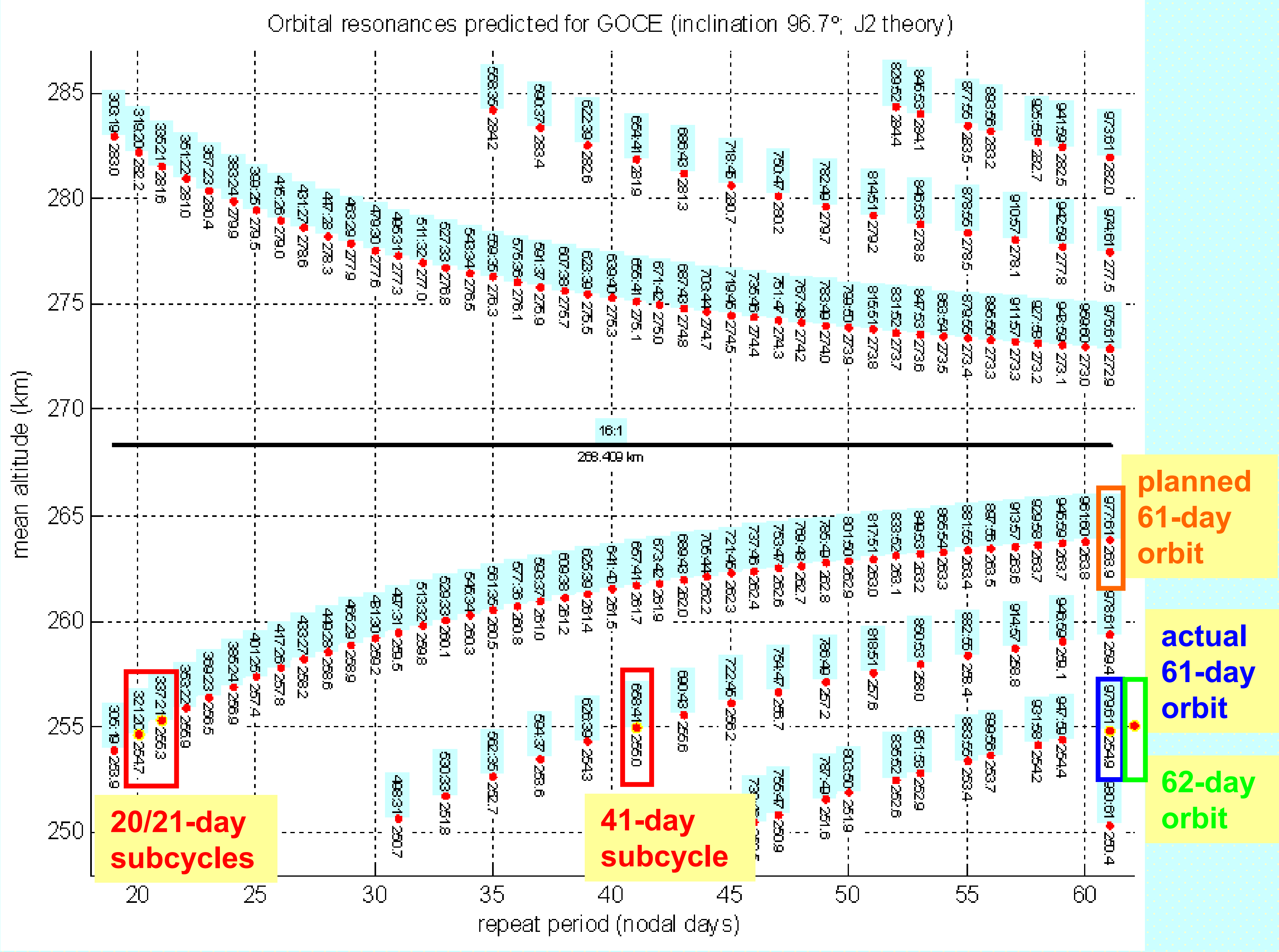
- What happens when **all other orbital perturbations** (geopotential, lunisolar, tides, radiation, …) are added?
  - ➢ **Peaks** in histograms **widened**
  - ➢ **Repeat** character is **kept**
  - ➢ Earth coverage **graphs** almost the **same** (0.02° ↔ 2 km)











Orbital resonances predicted for GOCE (inclination 96.7°; J2 theory)
mean altitude (km)
repeat period (nodal days)
16:1
268.409 km
planned 61-day orbit
actual 61-day orbit
62-day orbit
20/21-day subcycles
41-day subcycle

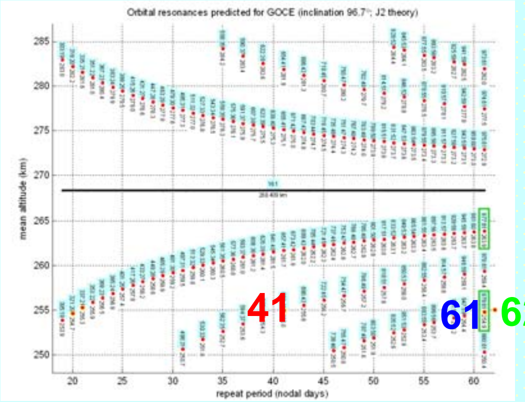
Orbits near the actual 61-day orbit of GOCE

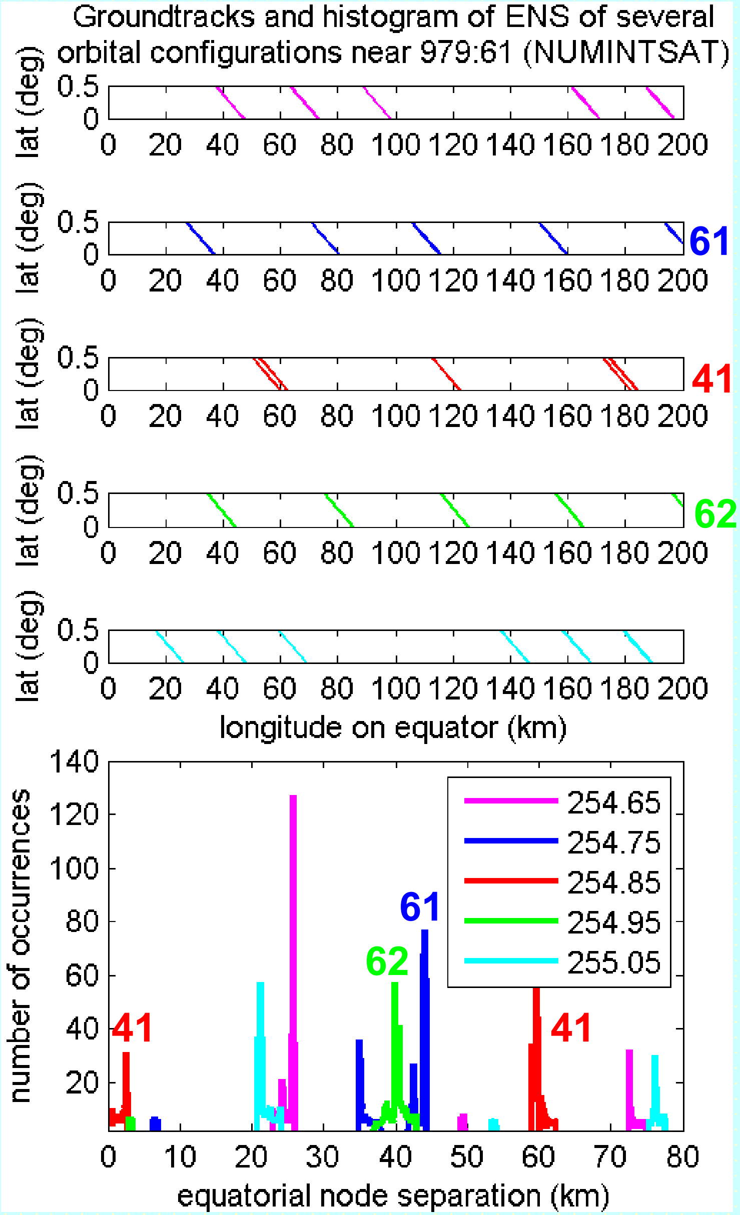
- Equator with groundtracks after 65 days
- Different mean altitudes

Repeat orbits:

- **61**-day (selected for MOP1)
- **41**-day subcycle

- **62-day** orbit compared with **61-day**
  - has ***more regular*** groundtrack grid
  - is only by ***200 m higher***





The 145-day orbit with 62/83 day subcycles

Planned **2327:145** repeat orbit

- node spacing ≈ **17.2 km**

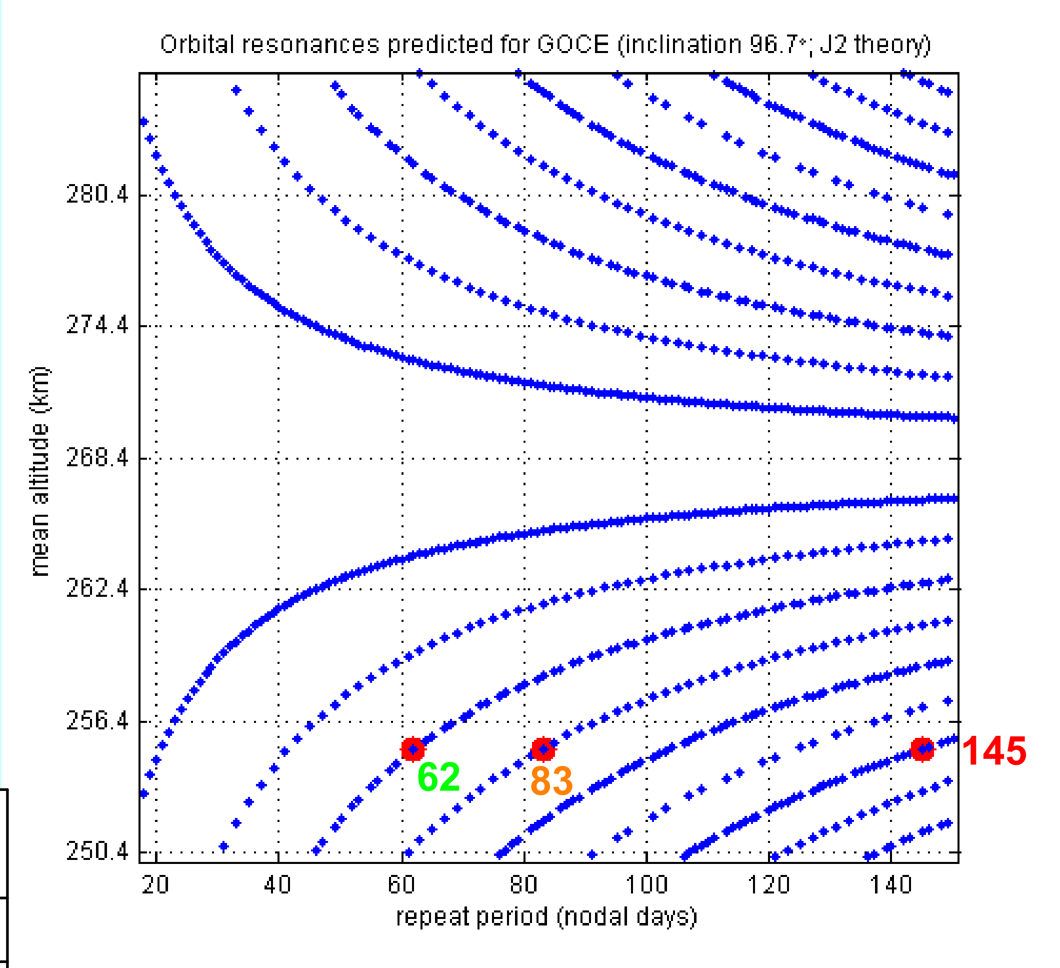
Nearest repeat orbits

- **62**-day, lower by **30 m**
- **83**-day, higher by **23 m**

Ion thruster performance ±50 m

145-day repeat is a good choice
→ node spacing at least

- **40.3 km** for **62**-day repeat
- **30.1 km** for **83**-day repeat

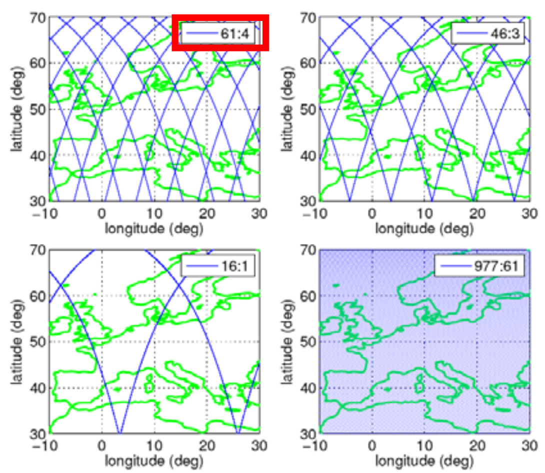


Resonant orbits ordered by height		
D	R	h (km)
1653	103	255,062
995	**62**	255,105
2327	**145**	255,135
1332	**83**	255,158
1669	104	255,19

Rationale behind fine orbit tuning & conclusions

- Without "good" coverage
  even the most sophisticated space instrument
  would not produce "good" geopotential coefficients!

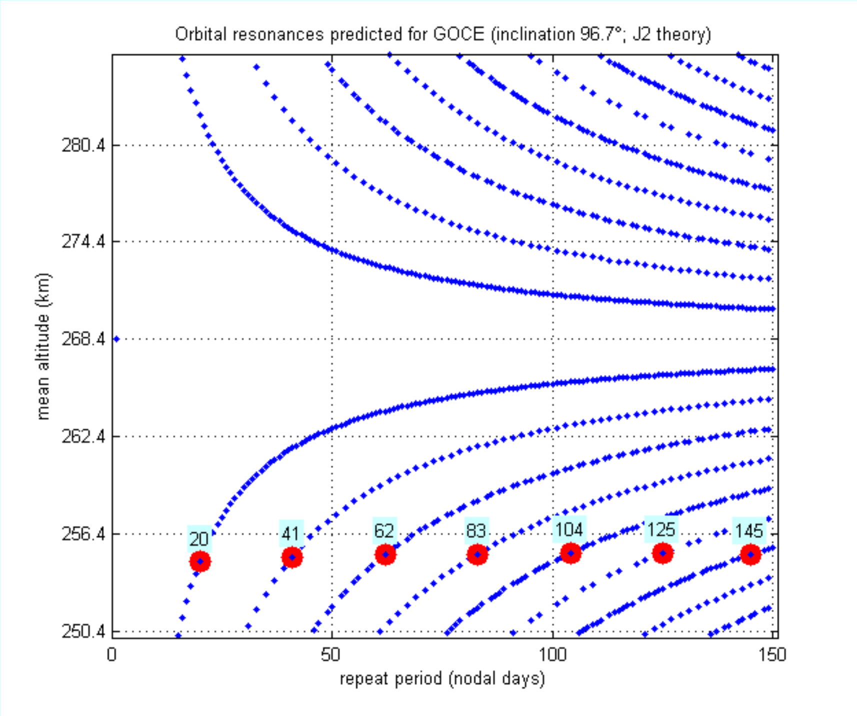
- CHAMP and GRACE experience → ESA sought
  for optimally dense and regular groundtrack grid

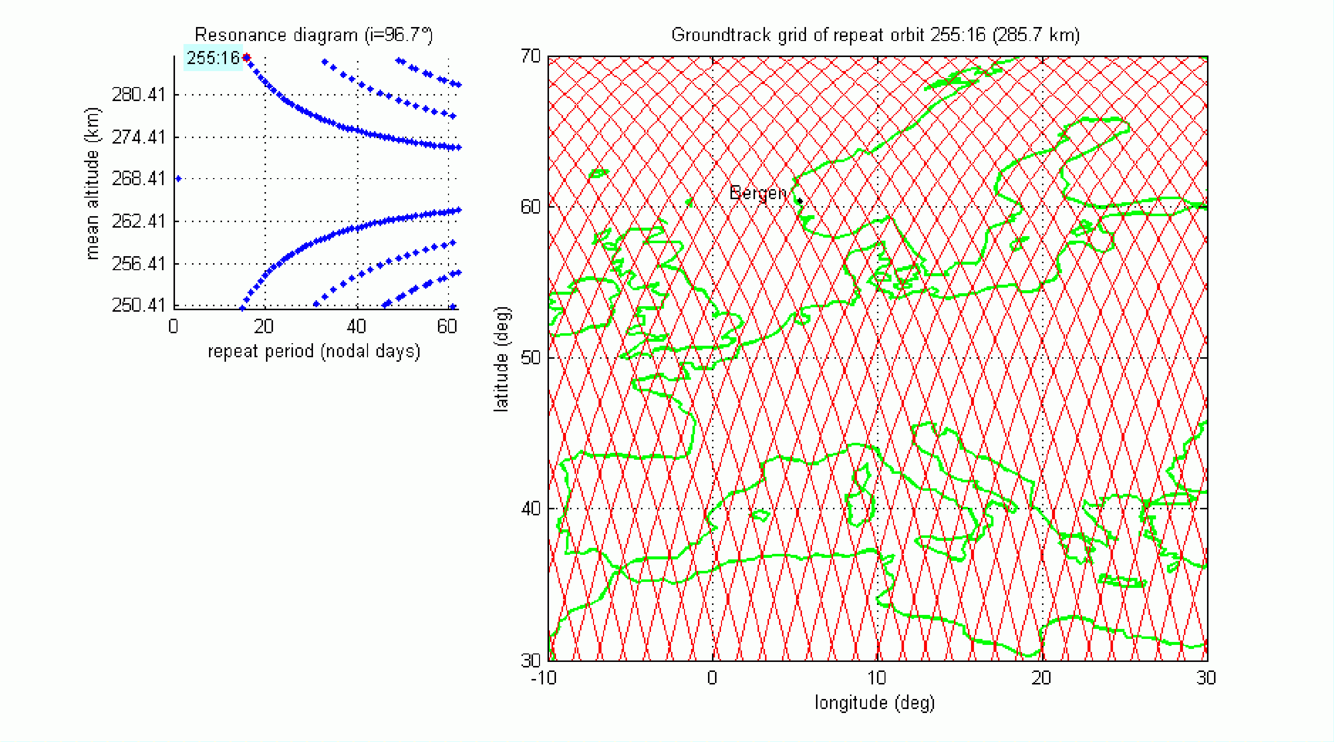


- A small shift in altitude may considerably affect the full utilization of the accuracy of the instrument

- Heights of highlighted orbits: only ±180 m, groundtrack density is extremely different

- Highlighted orbits also differ in regularity of their coverage pattern





Animation: Sequence of „stationary“ groundtrack grids as the altitude of the satellite is decreasing.

Thank you for your attention

- For details and references, see paper in proceedings