A methodology to choose the orbit for a double-pair-scenario future gravity satellite mission

Experiences from the SC4MGV project

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Orbit selection
Definition of scientific requirements

Basic scientific requirements:

3-day solutions with 1 mm precision and 500 km spatial resolution

10-day solutions with 1 mm precision and 150 km spatial resolution
Definition of scientific requirements

**Basic scientific requirements:**

3-day solutions with 1 mm precision and 500 km spatial resolution

10-day solutions with 1 mm precision and 150 km spatial resolution
Impact factors

- Spatial resolution
- Temporal resolution
- Technical feasibility
- Science benefit
- Aliasing
- Homogeneity
- Geographical extent
- Repeatability
- Precision

Search space
Basic considerations

Based on experience of previous studies the search space can be limited to:

• repeat mode \((\beta/\alpha)\) of each pair

• \(h \geq 340\) km \((\text{air drag considerations})\)

• inclination of polar pair between 88° and 92° \((\text{minimizing polar gap})\)

• inclination of inclined pair within 65°-75° or 105°-115°

• intersatellite distance between 75-100 km \((\text{technical constraints})\)
Genetic algorithm approach

The resulting search space is scanned using a genetic algorithm:

- Quick-look tool (no orbit integration but calculation along nominal orbit)
- Signal and error based on ESA mass transport model (Gruber et al. 2011)
  - signal: hydrology + ice + solid Earth
  - error: GOT4.7-EOT08a + 10% of atmosphere and ocean + 5% random
- Testing the global RMS of a single (first) 10-day solution
- Evaluation of 3000 candidates (massive numerical effort)
### Orbit scenarios for baseline

<table>
<thead>
<tr>
<th>Scenario</th>
<th>β/α [rev./nodal day]</th>
<th>Inclination [°]</th>
<th>Altitude [km]</th>
<th>Sub-cycle [nodal days]</th>
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<tbody>
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<td>484/31</td>
<td>89</td>
<td>363.3</td>
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<td>478/31</td>
<td>66</td>
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<td>89</td>
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<td>70</td>
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<td>342.5</td>
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Scenario selection
## Evaluation criteria

<table>
<thead>
<tr>
<th>Class</th>
<th>Measure</th>
<th>Level</th>
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<tbody>
<tr>
<td>Orbit</td>
<td>Orbit residuals</td>
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<tr>
<td></td>
<td>Sampling and ground track coverage</td>
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<tr>
<td>Spectral</td>
<td>Degree RMS (including spread of solution)</td>
<td>2</td>
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<tr>
<td></td>
<td>Cumulative geoid errors</td>
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<tr>
<td></td>
<td>Signal-to-noise ratio</td>
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<tr>
<td></td>
<td>Isotropy</td>
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<td>Spatial</td>
<td>Global RMS</td>
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<td>Basin RMS</td>
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<td>Latitude and longitude dependent RMS</td>
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<td></td>
<td>Correlation</td>
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<tr>
<td>Time series</td>
<td>Equivalent water height</td>
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<tr>
<td></td>
<td>Total water storage</td>
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<td>Loading</td>
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</table>

and many more …
Orbit configuration (sampling) (Level 1)
Groundtrack

Scenario 1

Scenario 2

Scenario 3

Scenario 4

Scenario 5
Equator sampling

Scenario 1

Scenario 2

Scenario 3

Scenario 4

Scenario 5
Degree RMS and Isotropy (Level 2)
Degree RMS

Degree RMS

Gain

\[ \text{Degree RMS} \]

\[ \text{Gain} \]

\[ \text{Unitless} \]

\[ 10^{-12} \]

\[ 10^{-13} \]

\[ 0 \]

\[ 20 \]

\[ 40 \]

\[ 60 \]

\[ 80 \]

\[ 100 \]

\[ 120 \]

\[ \text{SNR} \]

\[ 10^0 \]

\[ 10^1 \]

\[ 10^{-1} \]

\[ 0 \]

\[ 20 \]

\[ 40 \]

\[ 60 \]

\[ 80 \]

\[ 100 \]

\[ 120 \]
Assignment of error sources
Assignment of error sources
Assignment of error sources
Spatial error pattern (Level 2)
Unfiltered spatial pattern

Scenario 1

Scenario 2

Scenario 3

Scenario 4

Scenario 5
Filtered spatial pattern

Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Mean-filtered spatial pattern

Scenario 1

Scenario 2

Scenario 3

Scenario 4

Scenario 5
Time series analysis (Level 3)
Total water storage change

Scenario 1

Scenario 2

Scenario 3

Scenario 4

Scenario 5
Southern Chile

South Chile, Pacific Coast – total water storage change

<table>
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<tr>
<th></th>
<th>Trend [mm/yr.]</th>
<th>Annual amp. [mm]</th>
<th>Phase [days]</th>
<th>Semi-annual amp. [mm]</th>
<th>Phase [days]</th>
<th>Residual [mm]</th>
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<td>-0.01</td>
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</table>
Summary

• We choose scenario 5 as baseline scenario.

• GA needs better optimization criterion:
  – Testing a single solution is equivalent to testing a static field.
  – Time-variable signal needs to be tested.

• Impact of the sampling pattern needs to be understood. (e.g. isotropy, aliasing, …)

• Scenario selection needs evaluation on all levels of calculation and application.