Institute for Astronomical and Physical Geodesy
Technische Universität München

Winter Semester 2017/2018

ESPACE: Orbit Mechanics, Exercise 3
Integration of Satellite Orbits with Different Force Models

IAPG has developed a numerical orbit integration software, which is able to deal with all gravitational and non-gravitational forces. The software is operated with a comfortable graphical user interface. As numerical integrator an Adams-Moulton multi-step procedure is applied. In this exercise, orbits of different satellites applying different force models shall be computed and compared against each other. The impact of the individual forces on the satellite orbits shall be visualized. In particular the following tasks shall be completed.

1. Load the file „Integrator.zip“ from Moodle. The size of the zip file is 14 MB. Extract all files into a separate directory. In this directory you will find the executable program (bahn.exe) as well as a number of supporting files, which are required for computation of the forces. Perform all computations in this local directory and avoid changing to different directories.

2. Compute the orbits for the GRACE and GPS satellites with different force models for one day. The following general parameters have to be used:
   For GRACE:
   - Initial Conditions: Generate initial conditions with Default-button!
   - Change time to: 1.8.2002
   - Start-, Stop Time: 0 – 1 day in [sec]
   - Do not change position vector, velocity vector and integrator specifications.
   - Step size: 10 sec
   - Precision: 1e-16
   - Change for the last two solutions in the table on page 3 the initial conditions as indicated and investigate their impact on the resulting orbit.

   For GPS:
   - Initial Conditions: Change position- [m] and velocity vectors [m/s] to:
     - o pos: 13147200.00000, 22771618.37727, 0.00000
     - o vel: -1943.65825355171, 1122.17161590072, 3205.25431294238
   - keep all other parameters as for GRACE.

   The force models to be applied are specified in detail in the table on page 3. Please follow these instructions in order to make the results comparable.

3. For Output („Output“ Button) choose the following parameters, which will be written to the output file (the output file has to be newly defined for each computation with “Choose Output File”):
   - Time
   - Orbit (inertial)
   - Velocity (inertial)
   - If Air Drag or Solar Pressure are applied in the force model the accelerations also shall be written to the output file in the orbit system (choose the appropriate buttons in the Output Mask on the right hand side).

4. Compute the differences between the orbits for each component (x,y,z) according to the specification in the table on page 3 and analyze them with an appropriate graphical tool (e.g. Matlab). Interpret the differences and the individual impact of the forces on the orbit. Additionally compare the surface forces (in the orbit system) between the GRACE and GPS satellites (only for the test cases indicated in the table). Plot the results and interpret them.
5. Prepare a table for GRACE and GPS showing the size of the individual effects (e.g. indicate minimum, maximum, RMS of the differences for one day). The size of the effects are computed from the orbit comparisons as they are specified in the table on page 3.

Additional remarks for using the orbit integrator software:

Gravity

- Load for the computations the indicated gravity field model via the "Choose Coefficient File" button in the folder "Gravity". In case the gravity field model is not used set the maximum degree of the spherical harmonic series to 0 (see in table).
- Use "Spherical Coordinates" as well as exact transformation between inertial and Earth fixed systems.
- For polar motion push the "Fill in" button. Then polar coordinates should appear in the appropriate fields. They are needed for the tidal forces. Therefore the button is only active if tidal forces are switched on.

Surface Forces / Atmospheric Force Model

Atmospheric Drag

- When choosing "Atmospheric Drag" one additional category appears (Atmospheric Force Model).
- In this case switch on "Wind Model".
- Choose the GRACE surface model with a satellite mass of 425 kg. Choose the same value also in case of GPS orbit integration (even if this does not correspond to reality).
- In "Atmospheric Force Model" choose "Only drag no lift". Switch on the button "Derive Air Density via Model". Then another category will be available „Atmosphere Parameters". For all other parameters choose the predefined values.
- In "Atmosphere Parameters" choose 3-h AP Values and the MSIS86 Model. Fill the empty fields using the "Fill-in" Button.

Solar Radiation Pressure

- Also in this case choose the GRACE surface model with a satellite mass of 425 kg. Choose the same value also in case of GPS orbit determination (even if this does not correspond to reality).

Tides

- When direct tides are switched on load the "Ephemeris File" bin2000.200 using the appropriate button.
- When Earth tides are chosen (all 3 components and polar tides) the gravity field must be loaded at least up to degree 4.
- When choosing ocean tides again the gravity field must be loaded at least up to degree 4. In addition choose the predefined values (Schwiderski, Maximum Degree/Order 10, Interpolation interval 3 min).

Please prepare a written report specifically focusing on the interpretation of the results in terms of plots and tables.

Due date for delivery of written report: Febraury 05, 2018

Please send your written report (as .pdf) to:

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ESPACE Orbit Mechanics, Exercise 3, Orbit Integration

Solution	Satellite	Gravity Field	Degree/Order	Atmospheric Drag	Solar Rad. Pressure	Direct Tides Sun & Moon	Indirect Solid Earth Tides	Indirect Ocean Tides	Compare to Solution
A	GRACE	GRIM5-C1	0	-	-	-	-	-	-
B	GRACE	GRIM5-C1	50	-	-	-	-	-	A
C	GRACE	GRIM5-C1	120	-	-	-	-	-	B
D	GRACE	GRIM5-C1	0	+	-	-	-	-	A
E	GRACE	GRIM5-C1	0	-	+	-	-	-	A
F	GRACE	GRIM5-C1	0	-	-	+	-	-	A
G	GRACE	GRIM5-C1	50	-	-	-	+	-	B
H	GRACE	GRIM5-C1	50	-	-	-	-	+	B
I	GRACE	GRIM5-C1	120	+	+	+	+	+	C
J	GRACE	EIGEN-1S	119	+	+	+	+	+	I
K	GPS	GRIM5-C1	0	-	-	-	-	-	-
L	GPS	GRIM5-C1	50	-	-	-	-	-	K
M	GPS	GRIM5-C1	120	-	-	-	-	-	L
N	GPS	GRIM5-C1	0	+	-	-	-	-	K & D*
O	GPS	GRIM5-C1	0	-	+	-	-	-	K & E*
P	GPS	GRIM5-C1	0	-	-	+	-	-	K
Q	GPS	GRIM5-C1	50	-	-	-	+	-	L
R	GPS	GRIM5-C1	50	-	-	-	-	+	L
S	GPS	GRIM5-C1	120	+	+	+	+	+	M
T	GPS	EIGEN-1S	119	+	+	+	+	+	S
U[1)]	GRACE	GRIM5-C1	0	-	-	-	-	-	A
V[2)]	GRACE	GRIM5-C1	0	-	-	-	-	-	A

* here only the surface forces (Atmospheric Drag of Solar Pressure) shall be compared in the orbit system as they are provided by the software in accelerations [m/s^2]. Here orbits (position, velocity) do not have to be compared.

1) change the initial conditions of the position by adding +1m to x,y,z. Initial conditions of velocities are unchanged (kept as in A to J)

2) change the initial conditions of the velocities by adding +1mm/sec to x,y,z. Initial conditions of positions are unchanged (kept as in A toJ).