

## List of Figures

1.1. Location of Merapi volcano	2
1.2. Pyroclastic flows of Merapi	2
3.1. Potential of a three-dimensional mass	11
3.2a. Hollow right-circular cylinder with segments of inner and outer radii $r_1$ and $r_2$ , angle $\Delta\theta$ , and height $\Delta h$ above (below) station.	17
3.2b. Schematic representation of zones and compartments used to compute terrain corrections at a station positioned in the centre of the grid.	17
3.3. Three-dimensional body producing attractions at point P	19
4.1a. Vertical gravity effect of a sphere at point P	21
4.1b. Vertical gravity effect of a sphere with $\Delta\rho = 1000 \text{ kg/m}^3$ , $R=1 \text{ m}$ and different depths $z = 1, 1.1, 1.2 \text{ m}$	22
4.2a. Vertical gravity effect of a thin rod at point P	23
4.2b. Vertical gravity effect of a thin rod dipping with inclination $\alpha = 45^\circ, 90^\circ, 135^\circ$ , $z = 1 \text{ m}$ , $\Delta\rho = 1000 \text{ kg/m}^3$ , $\Delta A = 1 \text{ m}^2$ , $L = 100$	23
4.3a. Vertical gravity effect of a rectangular prism which cross-section $\Delta A$ at point P	24
4.3b. Vertical gravity effect of a prism with depth $h_1 = 1 \text{ m}$ and $h_2 = 100 \text{ m}$ , $\Delta\rho = 1000 \text{ kg/m}^3$ , $\Delta A = 1 \text{ m}^2$	25
4.4a. Bodies for computing vertical gravity effect at P of rectangular parallelepiped with one corner at coordinates origin	26
4.4b. Bodies for computing vertical gravity effect at P of rectangular parallelepiped with none corner at the origin	26
4.4c. Vertical gravity effect of a rectangular parallelepiped with none corner at the origin with $z_1 = 1 \text{ m}$ , $z_2 = 2 \text{ m}$ , $x_2 - x_1 = 1 \text{ m}$ , $y_2 - y_1 = 1 \text{ m}$ ; the horizontal distant of $x_1, x_2, y_1, y_2$ are varying toward origin; $\Delta\rho = 1000 \text{ kg/m}^3$	27
4.5a. Vertical gravity effect of a vertical cylinder on point P located at the axis	27
4.5b. Vertical gravity effect of a vertical cylinder of cylindrical slice on point P located at the axis	27
4.6a. Vertical gravity effect of a thick vertical cylinder at any arbitrary off cylinder axis point P	29

4.6b. Vertical gravity effect of the thick vertical cylinder for $L \gg z$	31
4.7. Vertical gravity effect of a vertical cylinder at any arbitrary point P	32
4.8a. Vertical gravity effects of the thick vertical cylinder as calculated by programs grav_cylinder_1.m and grav_cylinder_2.m. The reference point P is on the axis (4.6a)	33
4.8b. Differences of the results of grav_cylinder_1.m, grav_cylinder_2.m	33
4.9. Schematic diagram of the surface forms and subsurface structures of various volcanic features	34
4.10. Combination model of sphere and dipping thin rod	35
4.11. Vertical gravity effect of a pipe filled with magma at different levels for the stations JRA15, JRA13, IPU0, and JRA100; the top of the pipe is near JRAK13	37
4.12. Contour map of vertical gravity effects dependent on magma height changes in the pipe at station JRA15; the green line represents the observed gravity changes between campaigns August 1999 and August 1997.	38
4.13. Combination model of sphere and vertical thick cylinder	39
4.14. Groundwater layers (hydrothermal system) around Merapi modeled with thick vertical cylinders of different densities	41
5.1a. The gravity repetition network loop1 and loop2; interval of height contour lines is 200 m.	45
5.1b. The gravity repetition network: stations of loop 3 and the profile along the north flank; interval of height contour lines is 100 m.	45
6.1a. Gravity changes at all stations of the Merapi network between the campaigns Merapi II – I, Merapi III – I, Merapi IV – I and Merapi V – I in $\text{nm/s}^2$ .	53
6.1b. Gravity changes at the stations of the second and third loop of the Merapi network between the campaigns Merapi II – I, Merapi III – I, Merapi IV – I and Merapi V – I in $\text{nm/s}^2$ .	54
6.1c. The gravity changes relative to campaign Merapi I at all stations.	55
6.2a. Gravity changes at all stations of the Merapi network between the campaigns Merapi II – I, Merapi III – II, Merapi IV – III and Merapi V – IV in $\text{nm/s}^2$	57

6.2b. Gravity changes at stations of the second and third loop of Merapi network between the campaigns Merapi II – I, Merapi III – II, Merapi IV – III and Merapi V – IV in $\text{nm/s}^2$ .	58
6.2c. Gravity changes between successive campaigns at all stations	59
6.3a. Height changes at all stations of the Merapi network between the campaigns Merapi II – I, Merapi III – I, Merapi IV – I and Merapi V – I in m	61
6.3b. Height changes at stations of the second and third loop of the Merapi network between the campaigns Merapi II – I, Merapi III – I, Merapi IV – I and Merapi V – I in m.	62
6.3c. Height changes relative to campaign Merapi I at all stations	63
6.4a. Height changes at all stations of the Merapi network between the campaigns Merapi II – I, Merapi III – II, Merapi IV – III and Merapi V – IV in m.	65
6.4b. Height changes at stations of the second and third loop of Merapi network between the campaigns Merapi II – I, Merapi III – II, Merapi IV – III and Merapi V – IV in m.	66
6.4c. Height changes between successive campaigns at all stations	67
7.1. Vertical gravity effects ( $\text{nm/s}^2$ ) of magma ascending in an inclined pipe of 20 m radius from the magma chamber at 0 m up to the surface at the stations JRA15, JRA13 and JRA100. The pipe reaches near to station JRA13 the surface.	69
7.2. Height changes of magma in the pipe as deduced from gravity changes at stations JRA13 and JRA15 between August 1999 and August 1997 using the “sphere and dipping thin rod model”.	70
7.3. Height changes of magma in the pipe as deduced from gravity changes at stations JRA13, JRA15 and JRA100 between August 2000 and August 1997 using the “sphere and dipping thin rod model”.	71
7.4. Magma height in the pipe of the “sphere and dipping thin rod model”.	72
7.5. Vertical gravity effects ( $\text{nm/s}^2$ ) at JRA13, JRA15 and JRA100 as function of a pipe (rod) filled with magma; the top of the rod reaches near JRAK13 the surface	73

- 7.6. Height changes of magma in the pipe as deduced from gravity changes at stations JRA13 and JRA15 between August 1999 and August 1997 using the “sphere and vertical thin pipe model”. 74
- 7.7. Height changes of magma in the pipe as deduced from gravity changes at stations JRA13, JRA15 and JRA100 between August 2000 and August 1997 using the “sphere and vertical thin pipe model”. 75
- 7.8. Magma height in the pipe of the “sphere and vertical thin pipe (rod) model” 76
- 7.9. Vertical gravity effects ( $\text{nm/s}^2$ ) of a vertical pipe filled with magma at JRA1, JRA4, JRA6, and JRA9; the top of rod reaches near JRAK13 the surface. 77
- 7.10. Vertical gravity effects ( $\text{nm/s}^2$ ) of a vertical pipe filled with magma at JRA0, BABA, MRIY, DELE, CEPO and KALI; the top of rod reaches near JRAK13 the surface. 78
- 7.11. Vertical gravity effects ( $\text{nm/s}^2$ ) of a vertical pipe filled with magma at BUTU, MUNT, BOYO, KLAT and MVOY; the top of rod reaches near JRAK13 the surface 79
- 7.12. Vertical gravity effect ( $\text{nm/s}^2$ ) as function of pipe length filled with magma at JRA13, JRA15 and JRA100; the top of rod near JRAK13 80
- 7.13. Height changes of magma in the cylinder as deduced from gravity changes at stations JRA13 and JRA15 between August 1999 and August 1997 using the “sphere and vertical thick cylinder model”. 81
- 7.14. Height changes of magma in the cylinder as deduced from gravity changes at JRA13, JRA15 and JRA100 between August 2000 and August 1997 using the “sphere and vertical thick cylinder model” 82
- 7.15. Magma height in the pipe of the “sphere and vertical thick cylinder model”. 83
- 7.16. Vertical gravity effects ( $\text{nm/s}^2$ ) as function of magma heights in the cylinder at JRA1, JRA4, JRA6 and JRA9; the top of the cylinder reaches near JRAK13 the surface. 84
- 7.17. Vertical gravity effects ( $\text{nm/s}^2$ ) as function of magma heights in the cylinder at JRA0, BABA, MRIY, DELE, CEPO and KALI; the top of the cylinder reaches near JRAK13 the surface. 85

- 7.18. Vertical gravity effects ( $\text{nm/s}^2$ ) as function of magma heights in the cylinder at the stations BUTU, MUNT, BOYO, KLAT and MVOY; the top of the cylinder reaches near JRAK13 the surface 86
- 7.19a. Plot of the resistivity distribution and the topography on the north-south-profile. Red: low resistivity; Blue: high resistivity. Clearly notable are the high surface resistivities, e.g. below the summit (<http://www.uni-koeln.de>). 87
- 7.19b. Model of 10 concentric cylinders with the axes at the summit of Merapi volcano representing different resistivities structures. 87
- 7.19c. Geometric size of the concentric cylinders (Held, 2002). 88
- 7.19d. Three dimensional view of the concentric cylinder model 88
- 7.20a. Observed (blue points and  $2\sigma$  error bars) and modeled (red points and line) gravity changes between campaigns I (August 1997) and II (February 1998); as constraints density changes of  $\pm 50 \text{ kg/m}^3$  are introduced. 90
- 7.20b. Observed (blue points and  $2\sigma$  error bars) and modeled (red points and line) gravity changes between campaigns I (August 1997) and II (August 1998); as constraints density changes of  $\pm 50 \text{ kg/m}^3$  are introduced. 90
- 7.20c. Observed (blue points and  $2\sigma$  error bars) and modeled (red points and line) gravity changes between campaigns I (August 1997) and II (August 1999); as constraints density changes of  $\pm 50 \text{ kg/m}^3$  are introduced 91
- 7.20d. Observed (blue points and  $2\sigma$  error bars) and modeled (red points and line) gravity changes between campaigns I (August 1997) and II (August 2000); as constraints density changes of  $\pm 50 \text{ kg/m}^3$  are introduced. 91