Space observations in Geophysics and Planetary Sciences

Overview of research carried out at the Department of Geophysics


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10 Years of the Czech Republic in ESA, November 14, 2018
Mercury

- tidally-locked planet
- spin-orbit resonance 3:2
- irregular surface insolation
- MESSENGER: topography and gravity data
- elastic shell loaded by density anomalies induced by lateral temperature variations (Tosi et al. 2015)
Earth
Swarm: Electrical conductivity of the Earth’s mantle

- accurate measurements of geomagnetic field from low orbits
- electrical conductivity as an important geophysical parameter related to the temperature, chemical and mineralogical composition of the Earth’s mantle
- part of the Level 2 chains and products
- radial conductivity profiles with sensitivity estimates
- towards 3-D conductivity models (Velímský 2013)
Swarm: Electrical conductivity of the Earth’s mantle

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Swarm: Magnetic Signatures of Ocean Circulation

- wind- and temperature-driven ocean circulation induces secondary magnetic field
- weak field on the surface but much stronger at ocean depths (Velímský et al. 2018)
- can we detect it in magnetic Swarm data?
- can we monitor long-term variability of ocean currents by satellite magnetic measurements?

2014-05-30 00:00:00

\[ h = 1800 \text{ m} \]
GOCE: Congo Basin

- accurate measurements of vertical gravity and vertical gravity gradient from GOCE
- model GOCO03S up to degree 220
- Helmert transformation
- derivation of a refined sedimentary model
- improved sedimentary model used to determine the vertical density stratification in the southeast Congo Basin (Martinec & Fullea 2014)
- surface density contrast with respect to surrounding rocks: 0.24–0.28 g/cm³
- decrease with depth of 0.05–0.25 g/cm³ per 10 km
PPGNET: GNSS Network in Western Greece

- cooperation with University of Patras and the Research Institute of Geodesy, Topography and Cartography; five GNSS stations; observation since November 2013
- reconstruction of relative motions

- with respect to Patras (PATR/PAT0): Paravola (PVOG) 12 $\text{mm/yr}$ NNE; Retsina (RETS) 9 $\text{mm/yr}$ NNE; → Trichonis Lake normal fault system depicts a slip rate of 3 $\text{mm/yr}$

- with respect to Paravola (PVOG): Rigani (RGNI) and Katochi (KTCH) display SSE movement in accordance with the Katouna strike-slip fault → existence of a microplate in the area
Mars

- Mars Global Surveyor: puzzling surface features in Isidis Planitia
- Hypothesis: massive paleoglacialion $> 3\text{Gyr}$
- Joint numerical (Souček et al. 2015) and geomorphological study (Guidat et al. 2015)
- Glaciation hypothesis allows explanation of surface features and their spatial relations
Europa

The Solar System:

- Sun: 1,352,468 km
- Mercury: 57,910 km
- Venus: 10,820 km
- Earth: 149,598,000 km
- Mars: 225,000 km
- Jupiter: 778,360,000 km
- Saturn: 1,433,500,000 km
- Uranus: 2,872,800,000 km
- Neptune: 4,488,000,000 km

Moons with colored frames are not to scale.

- Callisto
- Io
- Europa
- Ganymede
- Tethys
- Rhea
- Dione
- Enceladus
- Mimas
- Oberon
- Umbriel
- Ariel
- Miranda
- Triton
- Charon

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Geophysics and Planetary Sciences

10 Years in ESA
Europa: Formation of Double Ridges

- GALILEO: double ridges along faults: unique in the solar system
- friction on the fault may lead to melting → subsurface water lenses
- lenses are gravitationally unstable, water is quickly extracted (Kalousová et al., *JGR*, 2014)
- possible mechanism for double ridges formation (Kalousová et al., *JGR*, 2016)
Europa: Friction on Strike-Slip Faults

- morphological observations: near surface water
- possible explanation?
- friction on strike-slip faults (e.g. double ridge)

→ model: tidally loaded strike-slip fault within the ice shell

Figure 1: Sketch of the physical model. The arrows indicate the tidally-induced strike-slip forcing, the computational domain is represented by solid lines.
Ganymede and Titan

- **GALILEO & CASSINI:** ocean sandwiched between two ice layers
- Titan: exchange of CH₄ a Ar between the core and the atmosphere?
- melting and water transport through the HP ice layer
- exchange of volatiles is possible
- Ganymede: already ceased, Titan: may be ongoing (Kalousová et al. 2018; Kalousová & Sotin 2018)
Enceladus

- Cassini: global subsurface ocean, jets in the south polar region
- Tiger stripes: faults at the south pole
- Numerical modeling (Souček et al. 2016, Běhounková et al. 2017): huge impact of tiger stripes on tidal deformation of the moon and dissipation in its shell
CASSINI: equatorial ridge: a unique feature in the Solar System

- large flattening not consistent with current spin rate
- possible explanation: collision with another celestial body (Kuchta et al. 2015)
- creation of the ridge depends on initial temperature, rotation, and grain size
A trip through the Solar System...
A trip through the Solar System...and beyond
Tidal heating and spin-orbit locking of exoplanets

- Close-in exoplanets: extreme environments, influence of host star, strong tidal loading
- How much do they differ from the planets in the Solar system?
- Are they habitable?
- What is their interior structure and composition?
- Joint modelling of interior structure with the orbital and spin rate evolution
- Tidal locking → large temperature contrast on the surface

Proxima Centauri b
Even small eccentricity of the orbit leads to an extensive tidal heating (volcanic world?)
Heat transport in large terrestrial exoplanets

- Large terrestrial exoplanets are subject to much higher self-compression than the Earth mantle.

- Numerical models that are used to study their internal dynamics often neglect the compressible effects.

- Our results demonstrate that compressibility effects are important for mantle dynamic processes and consequently also for formation of planetary atmospheres and the existence of magnetic field through thermal coupling of mantle and core dynamic systems (Čížková et al. 2017).
A trip through the Solar System... and beyond

Our department offers a unique opportunity to students at undergraduate, graduate, and doctoral levels in the area of geophysical and planetological studies, deeply embedded into advanced physical and mathematical framework.

JOIN NOW!

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