Rosetta Workshop
Stara Lesna, 05-07 September 2018

3D thermal model of selected regions on 67P and comparison with MIRO data

Norbert Kömle, Wolfgang Macher, Günter Kargl

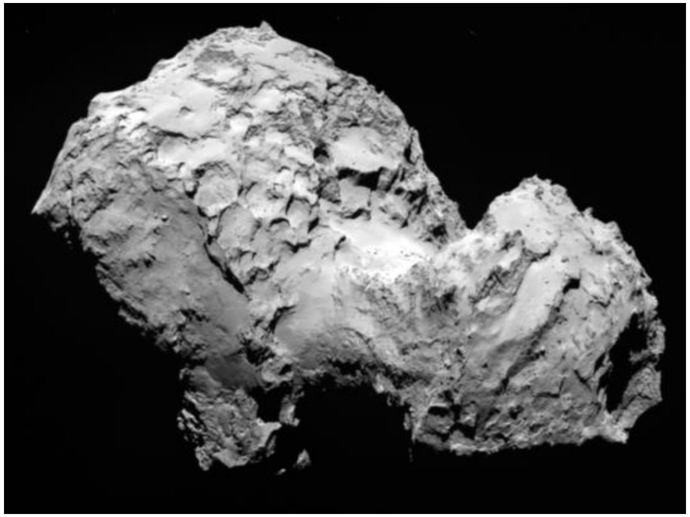
Space Research Institute

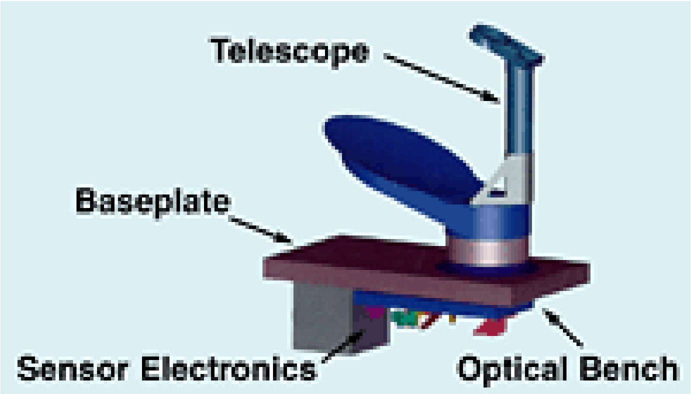
Austrian Academy of Sciences

Graz, Austria

Overview

- MIRO measurements at comet 67P
- Selected spots on cometary surface
- 3D heat transfer model
- Simulation results
- Comparison with MIRO data





MIRO is the only Rosetta instrument that that can measure temperature in the shallow subsurface of the comet (Schloerb et al. 2015).

MM-Channel: within 4 cm from the surface
SubMM-Channel: within 1 cm from the surface

Setup of 3D-model

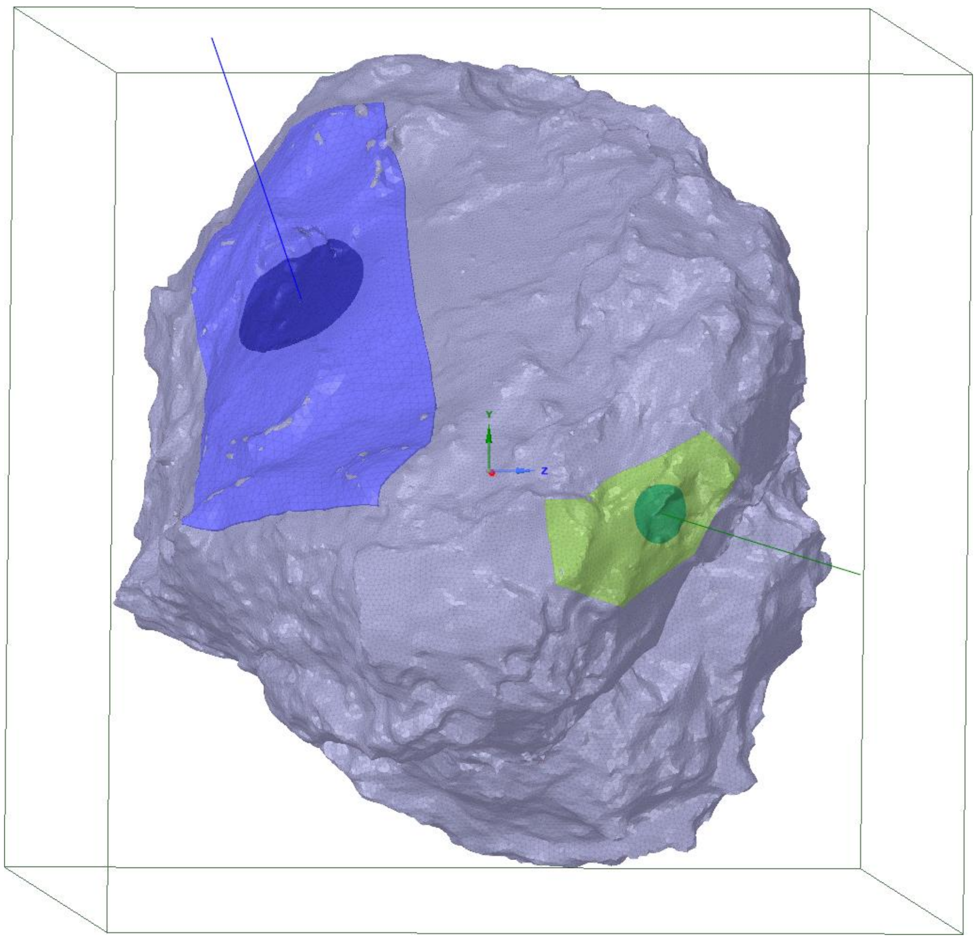
1. Extract regions of interest from SHAP5 digital terrain model and simplify and „repair“ geometry (Software used: SpaceClaim (ANSYS) → export to an ***stl*** data file

2. Setup thermal and radiation model in COMSOL and create suitable computational grid (triangular surface grid, boundary grid with high vertical resolution, tetrahedral volume grid)

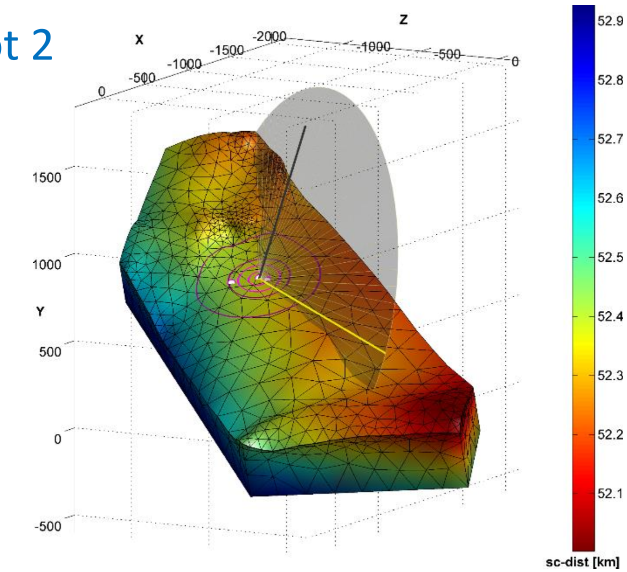
3. Run the model and save results in data files

4. Post-process and evaluate exported results mainly by a customized set of MATLAB programs

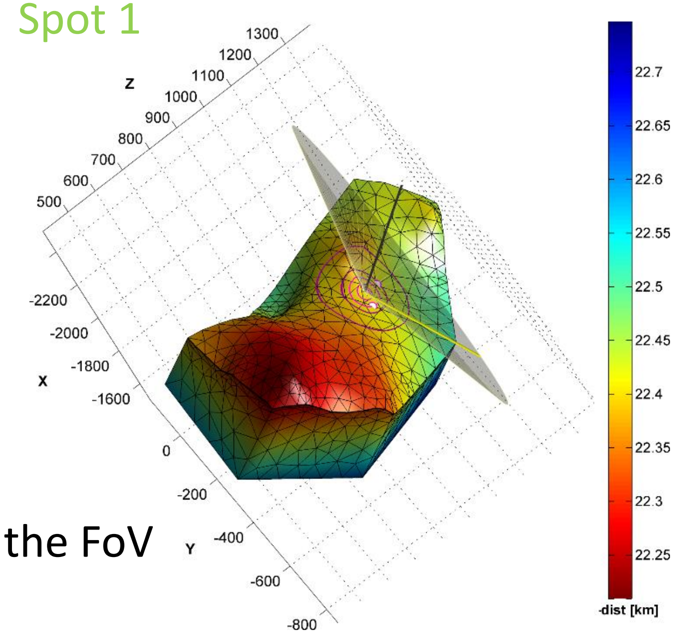
Selected regions on 67P



Spot 2



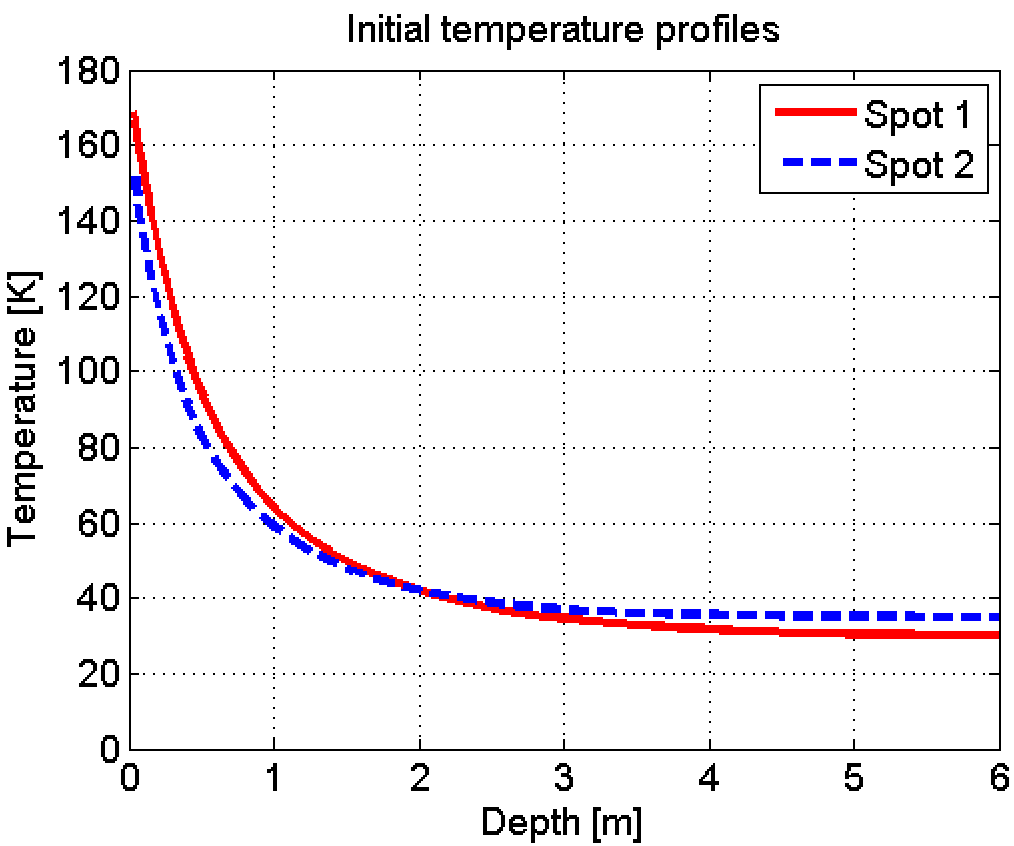
Spot 1



Circular areas: Field-of-View of the MIRO beam

Surrounding polygons: regions casting shadows on the FoV

Parameters for 3D model



Thermophysical parameters:

- Thermal conductivity
- Heat capacity
- Density

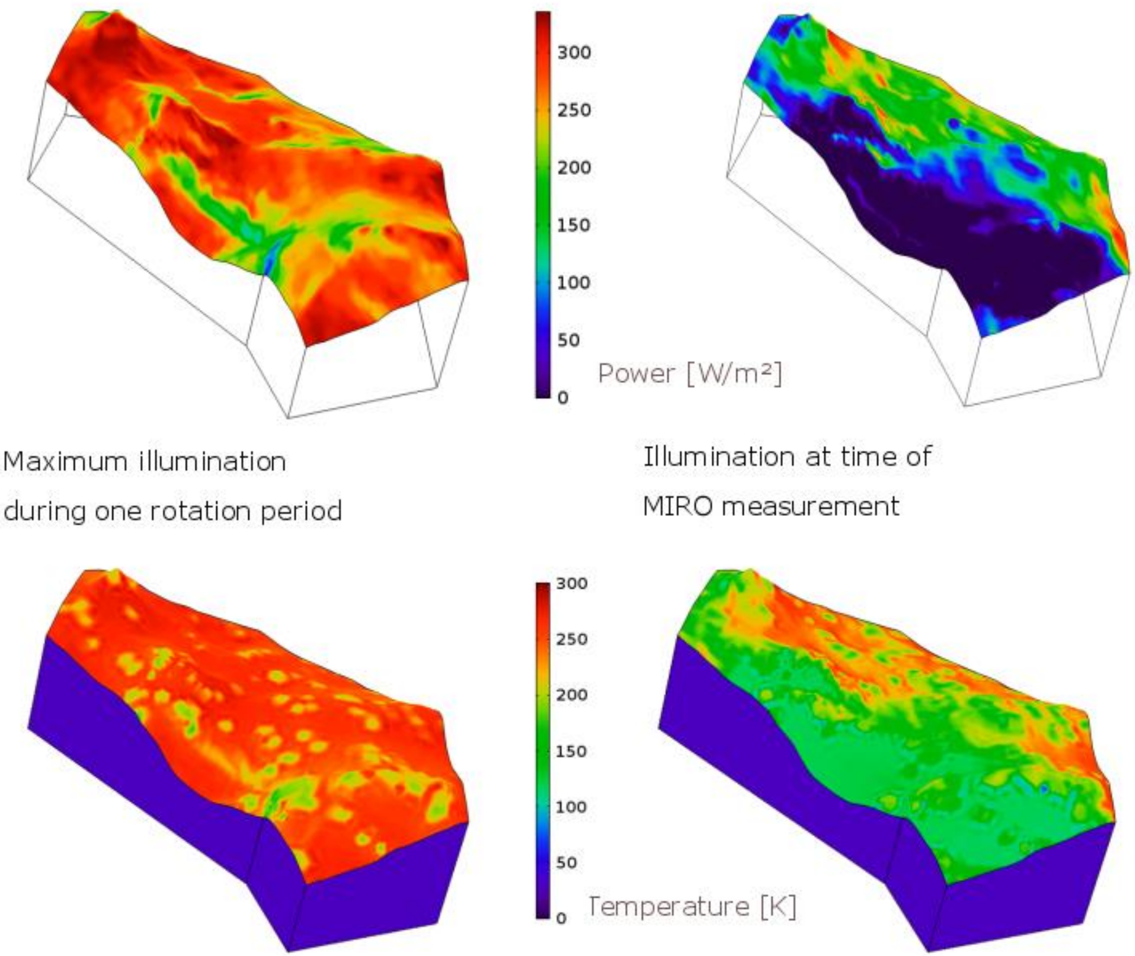
Radiation parameters:

IR-emissivity
Albedo

Initial conditions are based on computation results of a simple 1D-model computed ove many orbital periods of the comet. The full 3D model is then run over 8 rotational periods.

Region 1: illumination and surface temperatures

Spot 1



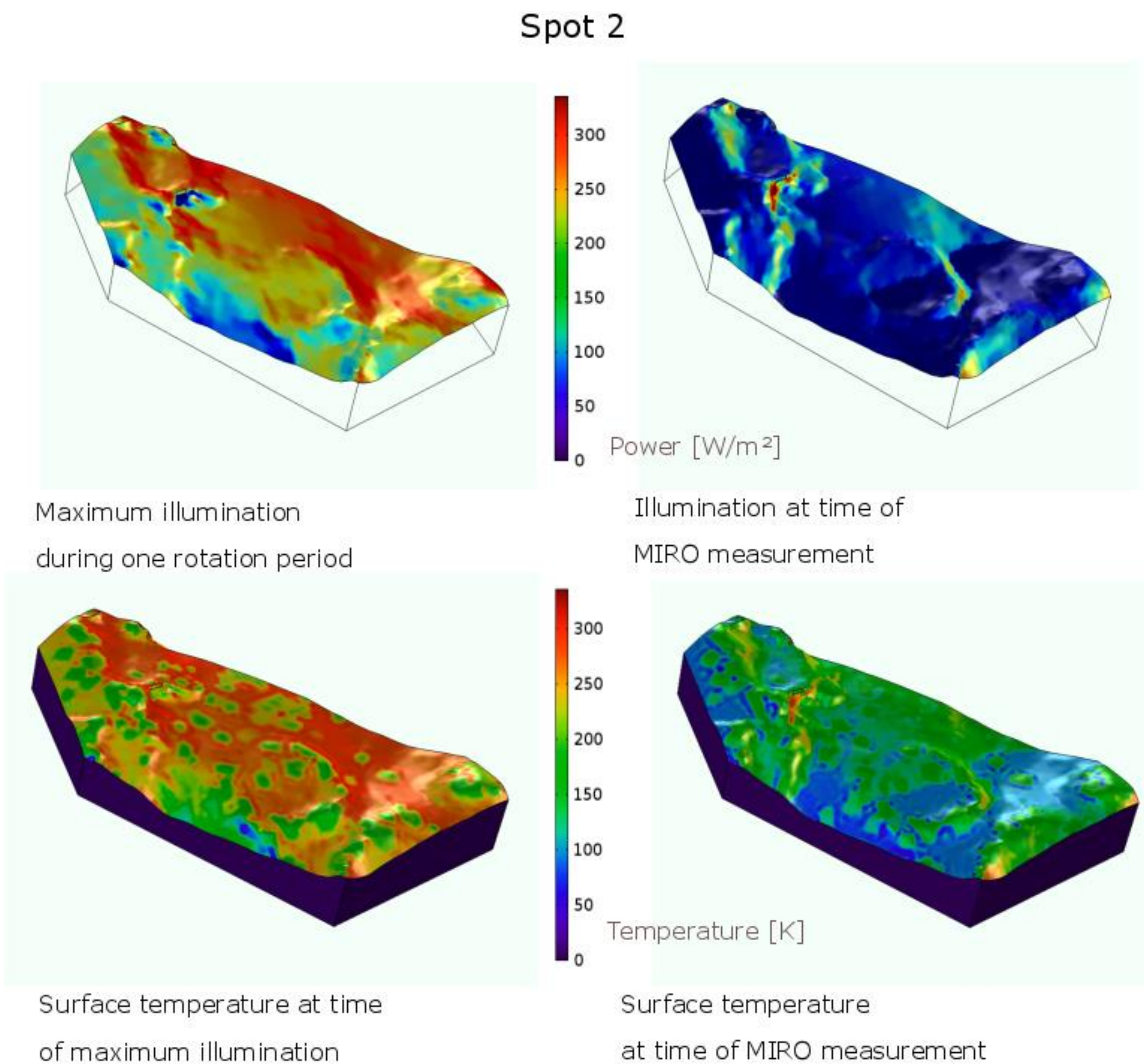
Maximum illumination during one rotation period

Illumination at time of MIRO measurement

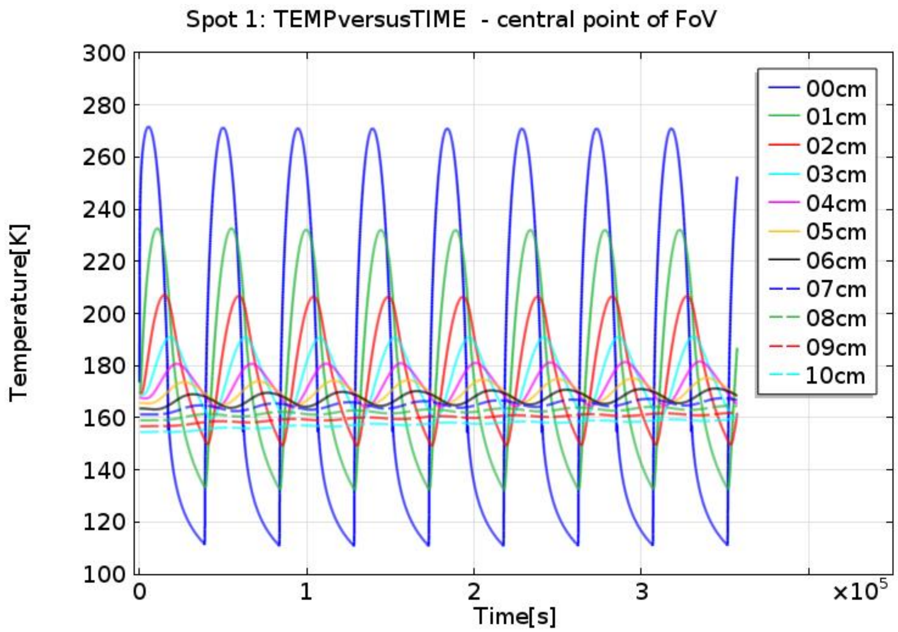
Surface temperature at time of maximum illumination

Surface temperature at time of MIRO measurement

Region 2: illumination and surface temperatures



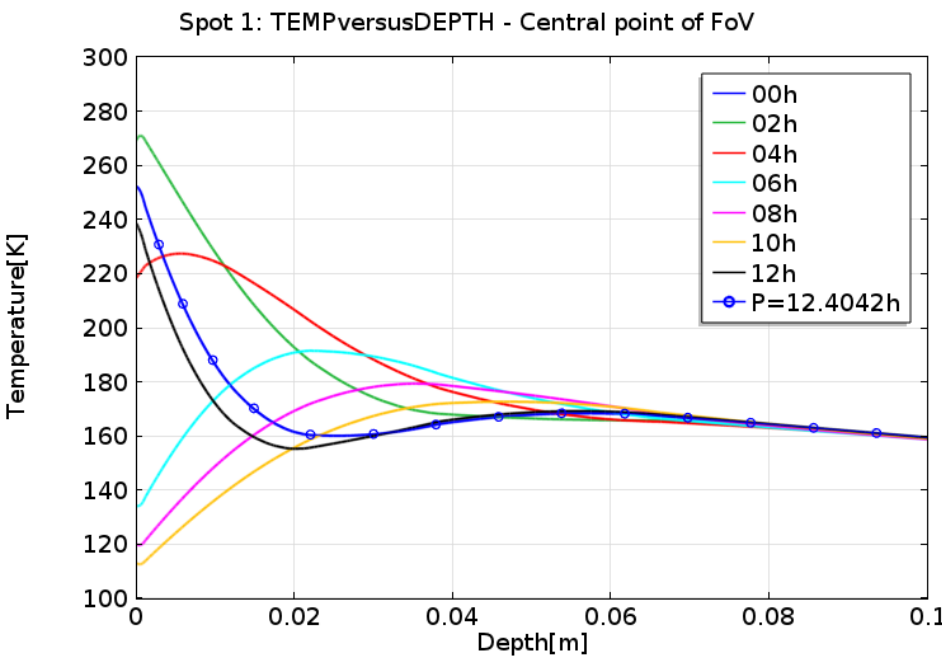
Spot1: Temperature variations within the MIRO FoV



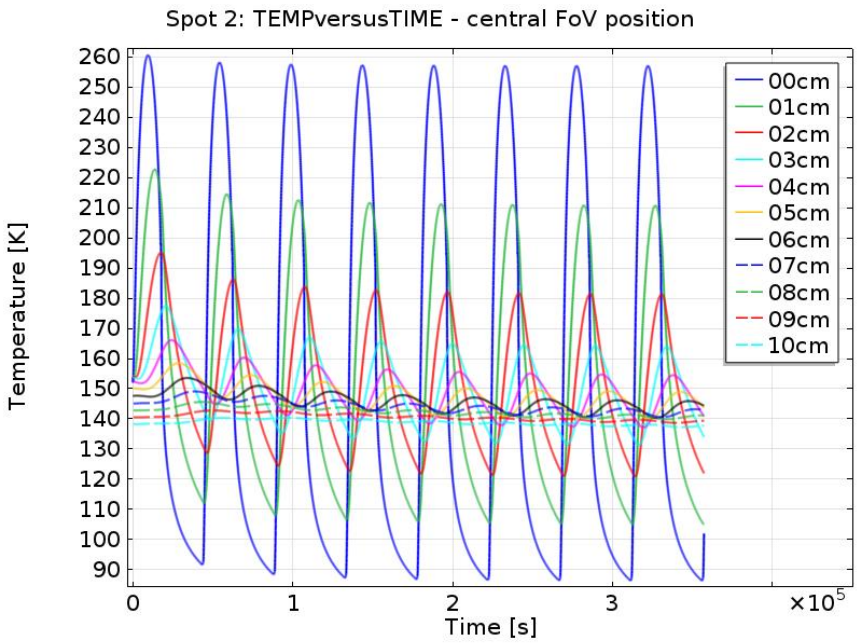
Temperature versus depth profiles for the last calculated rotation cycle

Note that after a full rotation period the temperature profile within 10 cm depth is very close to that of that at the begin of the period → well equilibrated!

Variation of the within a depth range of 10 cm below the surface. This corresponds to several thermal skin depths

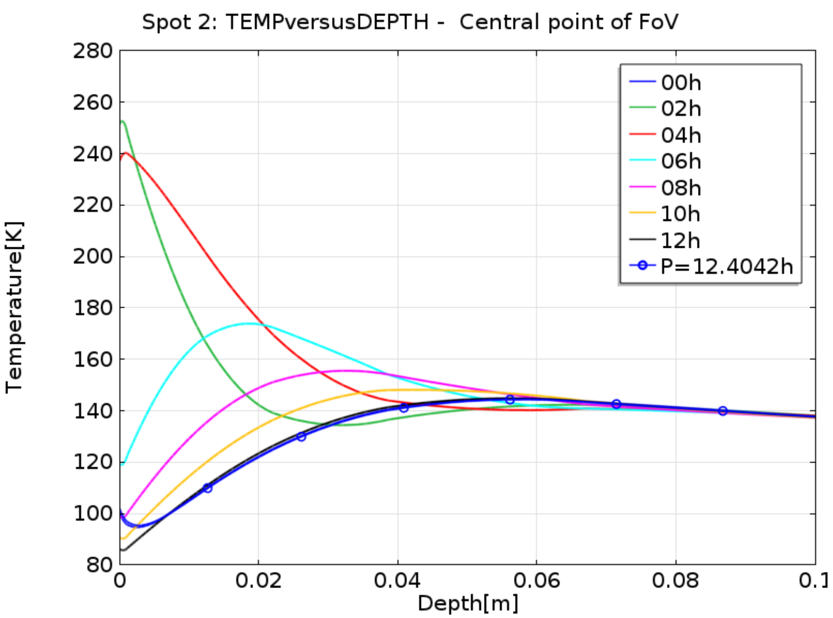


Spot2: Temperature variations within the MIRO FoV



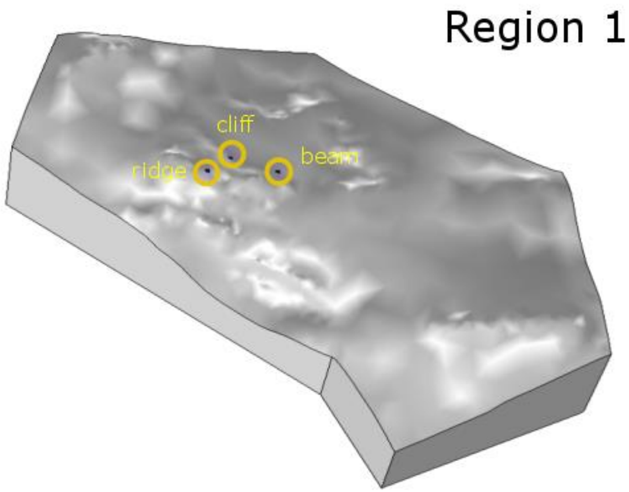
Temperature versus depth profiles for the last calculated rotation cycle

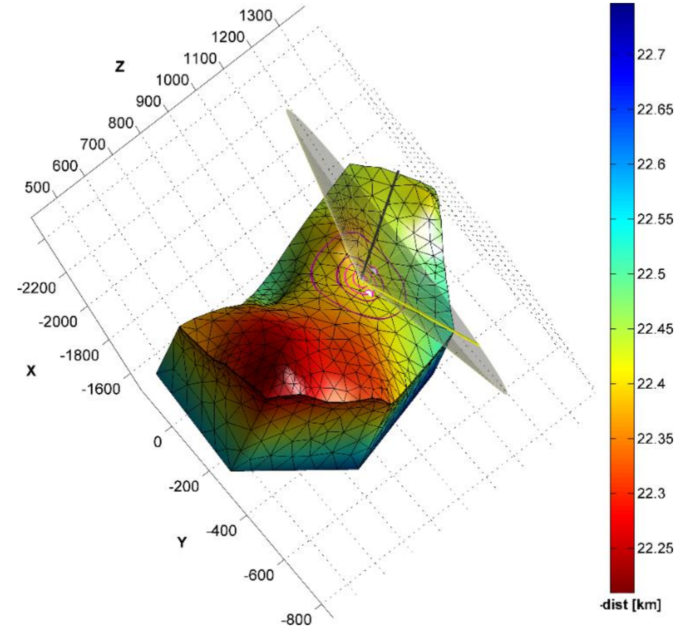
Note that after a full rotation period the temperature profile within 10 cm depth is very close to that of that at the begin of the period → well equilibrated!

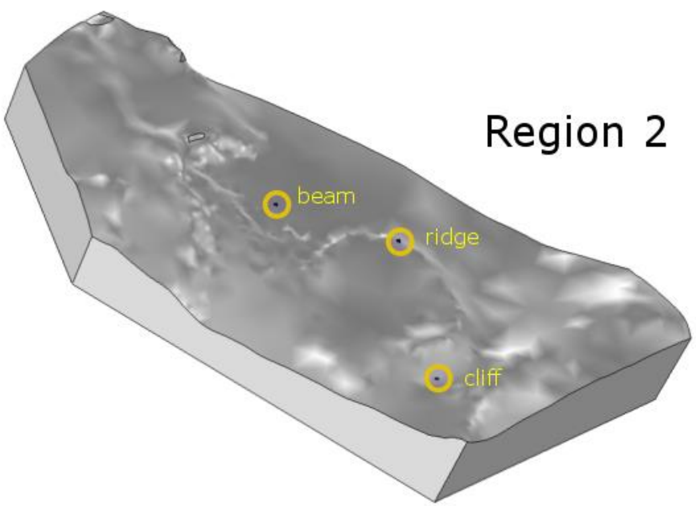


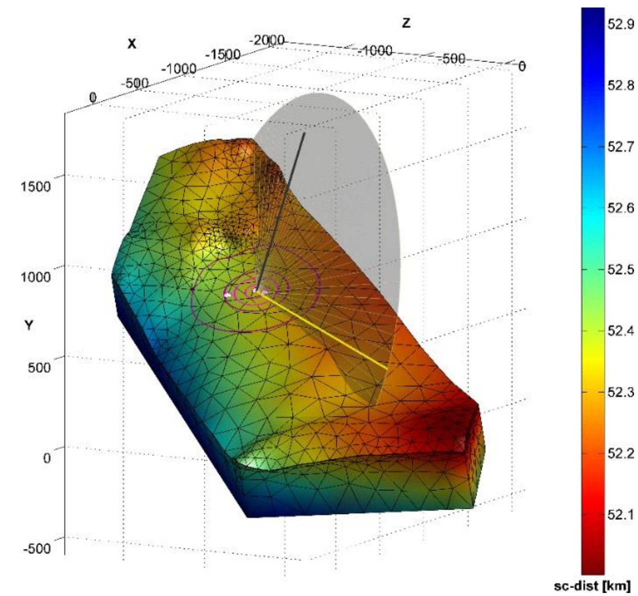
Variation of the within a depth range of 10 cm below the surface.   This corresponds to several thermal skin depths

Selected points on surface

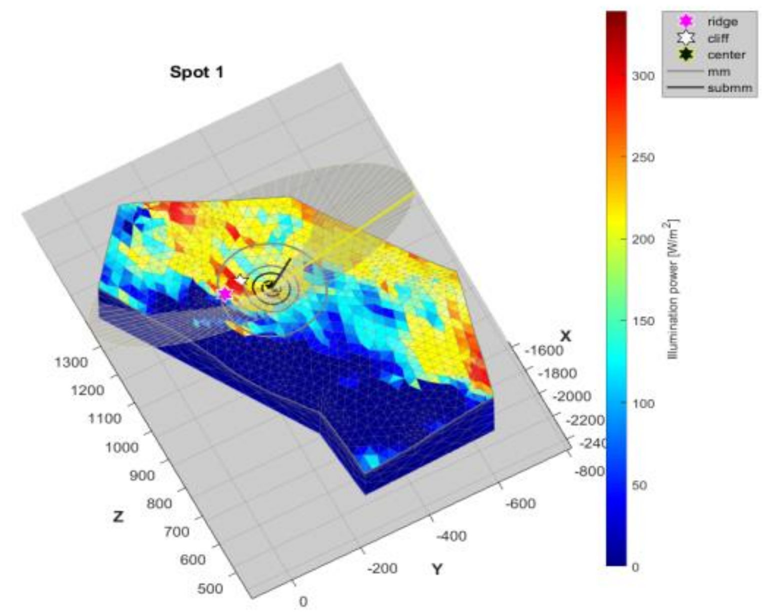


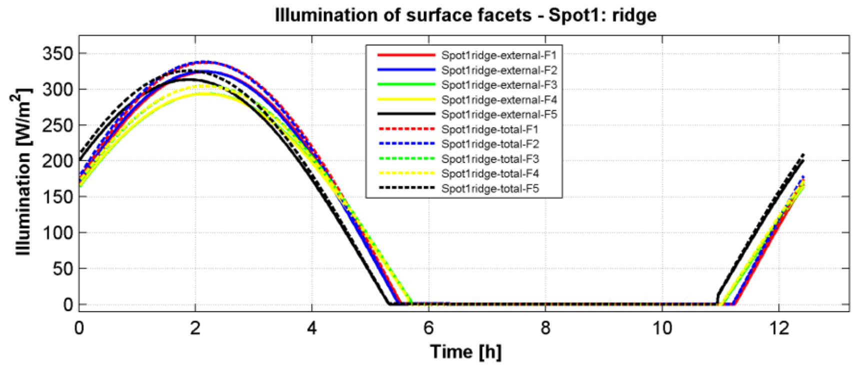


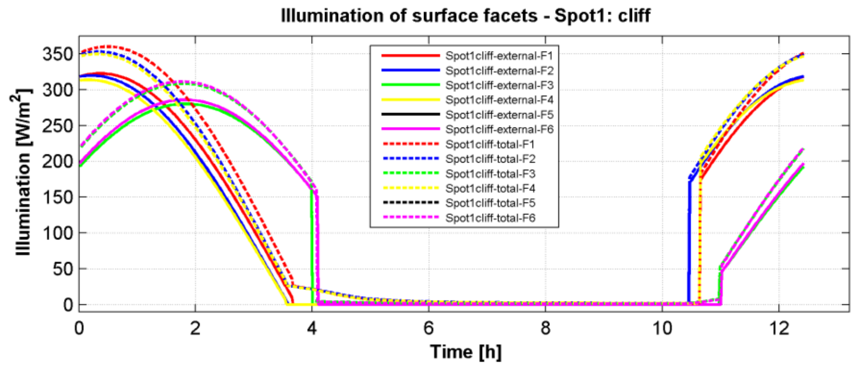


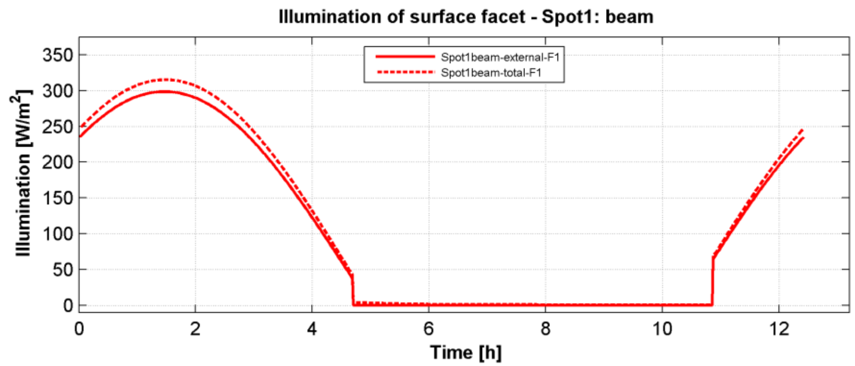


Ilumination of Region 1



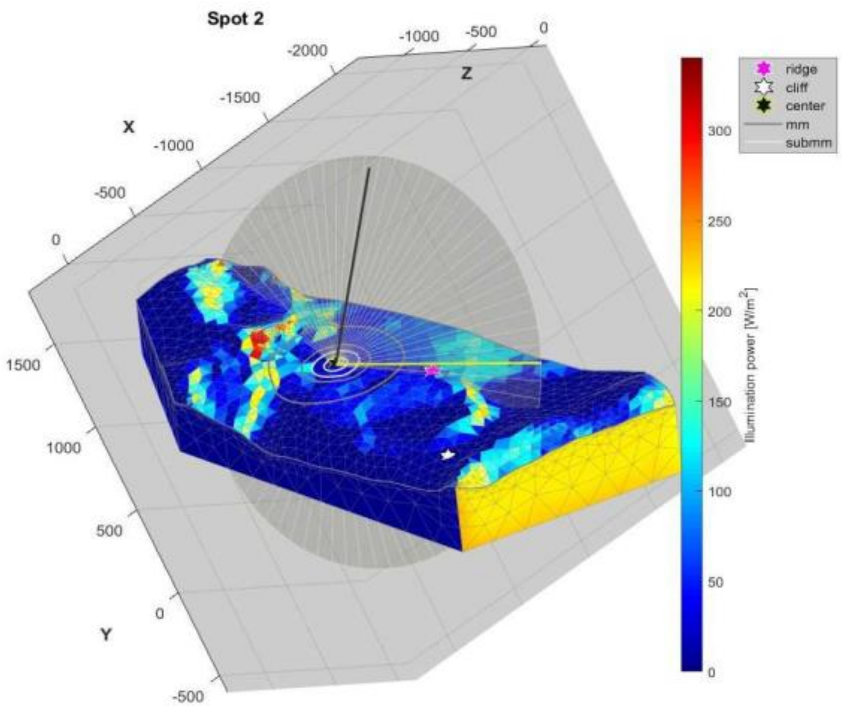


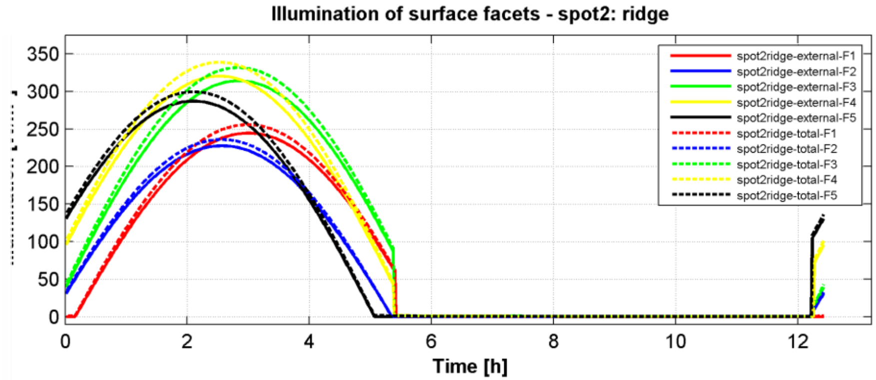


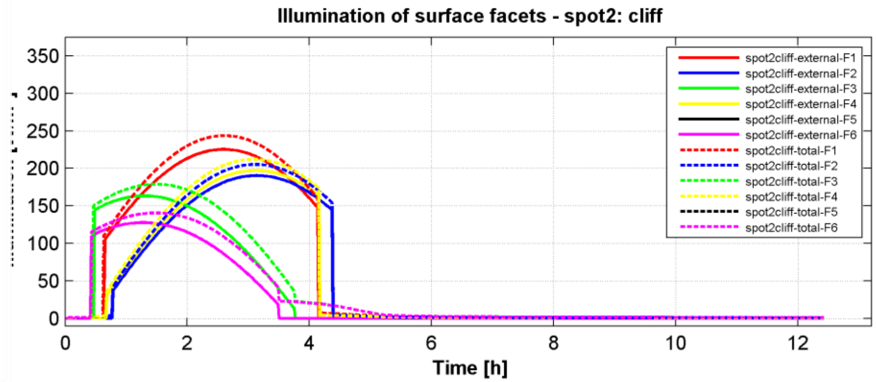


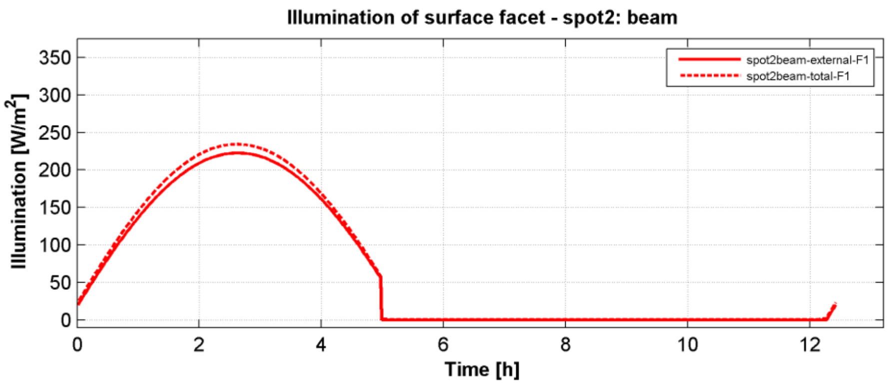
Direct illumination dominant! Indirect irradiation makes significant contribution near terminator – especially in „cliff“ region!

Illumination of Region 2









Direct illumination dominant! Indirect irradiation makes significant contribution near terminator – especially in „cliff“ region!

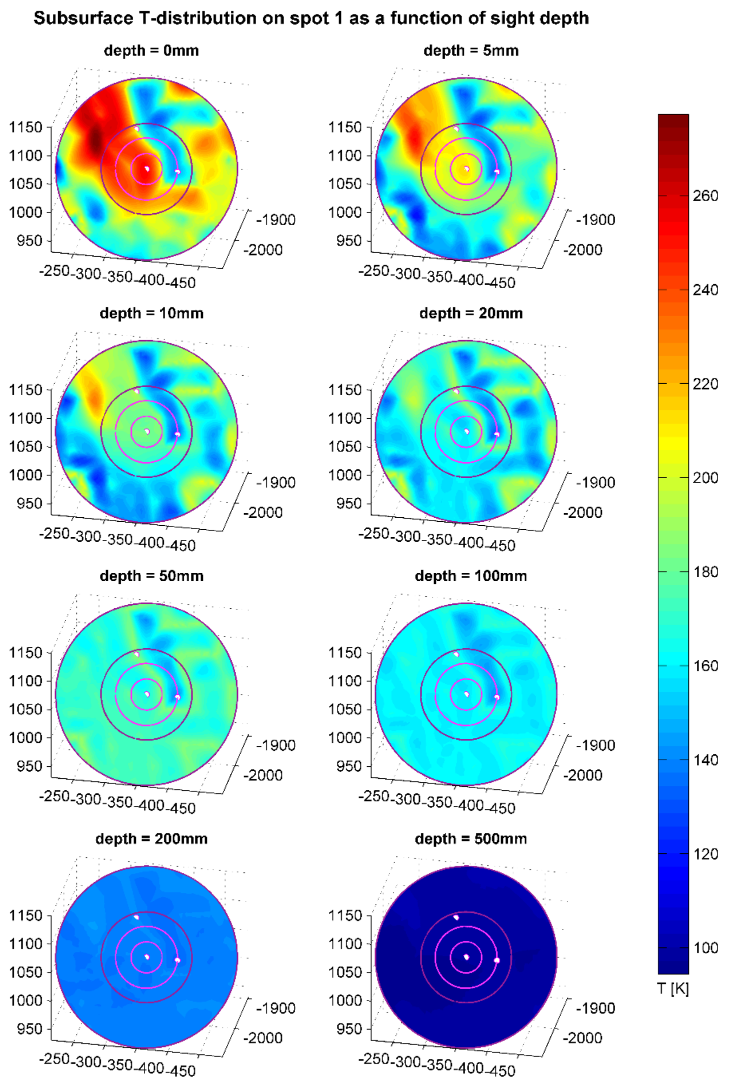
Evaluate MIRO data with 3D model

- Extract surface covered by MIRO beam from the simulated region.
- Construct parallel surfaces moved by certain depth increments towards the subsurface.
- Export this grid together with the simulated temperatures from COMSOL into MATLAB and calculate an average temperature over the volume covered by the MIRO beam (MM and SUBMM channel).
- This calculated average temperature can now be compared with the temperature value measured by the MIRO instrument.

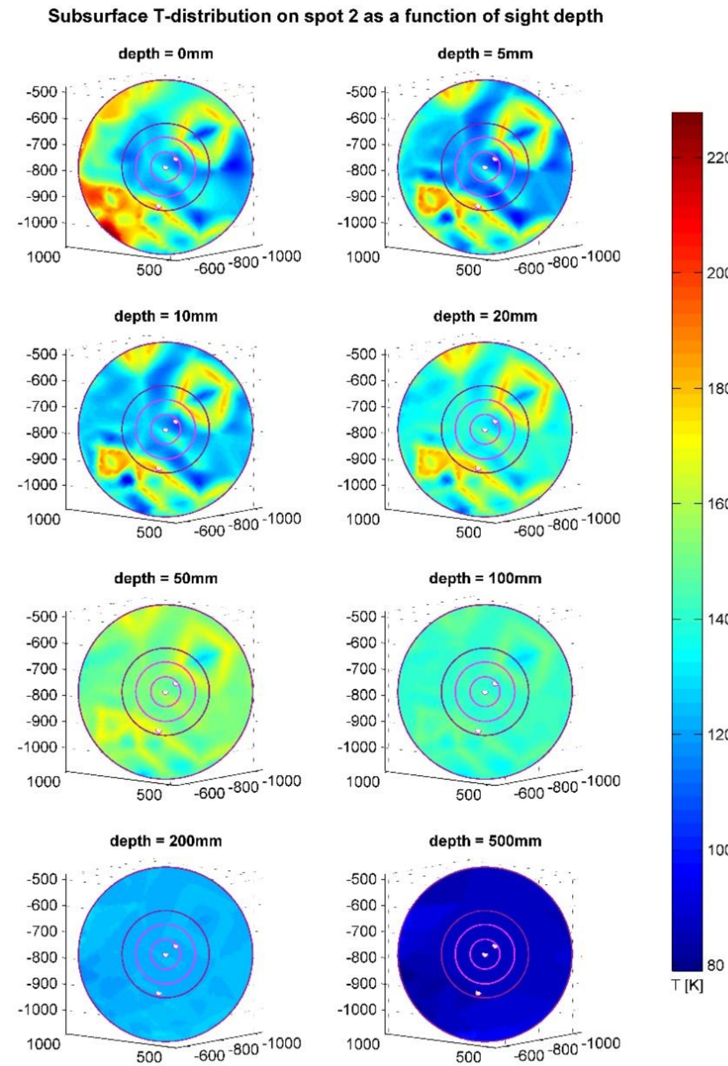
First results assuming constant antenna gain (work in progress):

Spot/Channel	T_simulated	T_measured
Spot 1/MM	173 K	175 K
Spot 1/SUBMM	186 K	172 K
Spot 2/MM	147 K	107 K
Spot 2/SUBMM	148 K	140 K

Simulated subsurface temperatures within MIRO FoV



Spot 1



Spot 2

Summary

The highly irregular surface of comet 67P demands a 3D thermal and radiation model in order to evaluate heat flow and energy balance correctly.

Indirect illumination of surface elements can play a significant role in particular in cliff and valley regions, where the elements „see“ a lot of „walls“ from the surroundings.

Appropriate integration and averaging of the simulated temperature field can be used to evaluate thermal parameters of the near surface region by comparison of simulation results with MIRO data.