

Numerical and Experimental Investigations of the Effective Thermal Conductivity of Snow

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Auxiliary Materials

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General Information

In the following, we provide the list and related information for all the samples used in this study. For each snow type [*Fierz et al., 2009*], a typical microtomographic sample is presented together with its main results in terms of effective thermal conductivity.

- **Figures x.1:** 3D images of the snow sample. The color coding of the images corresponds to the curvature field, which allows an easy representation of the 3D structure from planar images.
- **Figures x.2:** Estimations of the REV (the smallest fraction of the sample volume from which a variable representative of the whole can be determined) with respect to the thermal conductivity. It is estimated by calculating values of the thermal conductivity from several sub-volumes of increasing sizes. The REV is reached as soon as values remain constant when sub-volumes of calculations increase.
- **Tables x.1:** Numerical values of the diagonal terms of the effective thermal conductivity. For all the images of the study, the non diagonal terms are 100 times lower than the diagonal values and can be neglected.

List of the 30 Samples Used in the Study

Sample name	Snow type	Voxel size (μm)	Remarks	Main References
Fr	PP	4.91	Sampled at Col de Porte ¹ , 14 February 2002.	This study
I01	PP	4.91	Sampled at Col de Porte, 15 h after the snowfall.	Flin et al., 2004
I03	PP	4.91	62 h after the snowfall, under isothermal conditions at -2°C .	Flin et al., 2004
I04	PP	4.91	81 h after the snowfall, under isothermal conditions at -2°C .	Flin et al., 2004
I08	DF	4.91	297 h after the snowfall, under isothermal conditions at -2°C .	Flin et al., 2004
I15	RG	4.91	806 h after the snowfall, under isothermal conditions at -2°C .	Flin et al., 2004
I19	RG	4.91	1381 h after the snowfall, under isothermal conditions at -2°C .	Flin et al., 2004
I21	RG	4.91	1694 h after the snowfall, under isothermal conditions at -2°C .	Flin et al., 2004
I23	RG	4.91	2026 h after the snowfall, under isothermal conditions at -2°C .	Flin et al., 2004
P03	PP	8.48	Girose glacier ² , 20 cm depth, 17 March 2009.	Flin et al., 2011
P04	DF	8.588	Girose glacier, 40 cm depth, 17 March 2009.	Flin et al., 2011
P06	RG	6.158	Girose glacier, 60 cm depth, 17 March 2009.	Flin et al., 2011
P07	RG	8.609	Girose glacier, 70 cm depth, 17 March 2009.	Flin et al., 2011
P08	RG	8.552	Girose glacier, 100 cm depth, 17 March 2009.	Flin et al., 2011
P09	RG	6.158	Girose glacier, 120 cm depth, 17 March 2009.	Flin et al., 2011
P10	RG	6.103	Girose glacier, 165 cm depth, 17 March 2009.	Flin et al., 2011
P11	RG	8.588	Girose glacier, 65 cm depth, 1 March 2009.	Flin et al., 2011
P14	RG	6.154	Girose glacier, 80 cm depth, 1 March 2009.	Flin et al., 2011
P15	RG	6.158	Girose glacier, 170 cm depth, 1 March 2009.	Flin et al., 2011
H00	RG	8.609	Sieved snow, followed by isothermal conditions.	Flin et al., 2011
H01	MF	8.609	Grain coarsening of water-saturated snow and drainage after 1h.	Flin et al., 2011
H1-2	MF	8.590	Grain coarsening of water-saturated snow and drainage after 6h.	Flin et al., 2011
H02	MF	8.590	Grain coarsening of water-saturated snow and drainage after 24h.	Flin et al., 2011
H03	MF	8.609	Grain coarsening of water-saturated snow and drainage after 48h.	Flin et al., 2011
H05	MF	8.590	Grain coarsening of water-saturated snow and drainage after 142h.	Flin et al., 2011
Chamair	MF	10	Grain coarsening of water-saturated snow and drainage.	Coléou et al., 2001
E2b	FC	4.91	3 weeks under a $\text{TG} = 16 \text{ K m}^{-1}$, $T_{\text{mean}} = -3^{\circ}\text{C}$, sampled in the middle of the layer.	Flin et al., 2008
3A	DH	8.400	9 days under a $\text{TG} = 43 \text{ K m}^{-1}$, $T_{\text{mean}} = -4^{\circ}\text{C}$, sampled in the middle of the layer.	This study
4A	DH	8.397	13 days under a $\text{TG} = 43 \text{ K m}^{-1}$, $T_{\text{mean}} = -4^{\circ}\text{C}$, sampled in the middle of the layer.	This study
Grad3	DH	10	8 days under a $\text{TG} = 100 \text{ K m}^{-1}$, $T_{\text{mean}} = -5^{\circ}\text{C}$.	Coléou et al., 2001

Table 1: List of the snow samples used in the present work. Snow type is defined according to the International Classification for Seasonal Snow on the Ground [Fierz et al., 2009]: PP, Precipitation Particles; DF, Decomposing and Fragmented precipitation particles; RG, Rounded Grains; FC, Faceted Crystals; DH, Depth Hoar; MF, Melt Forms. Lines with gray background correspond to samples for which detailed information is provided below.

¹ 1325 m altitude, Chartreuse range, France.

² 3200 m altitude, Ecrins range, France.

Sample *Fr* - Precipitation Particles (PP)

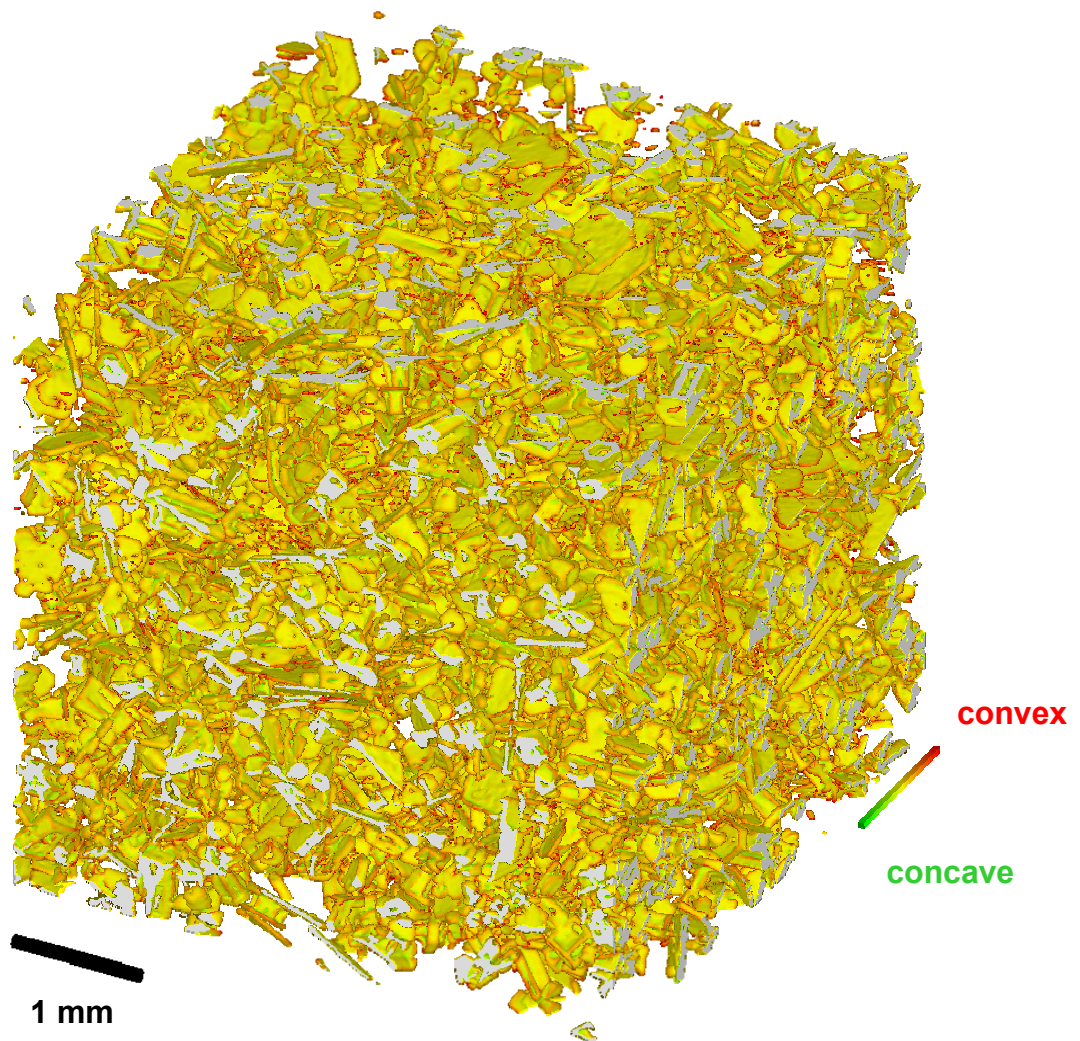


Figure 1.1: 3D visualization of the microtomographic image (size = 1192^3 voxels, 1 vox. = $4.91 \mu\text{m}$).

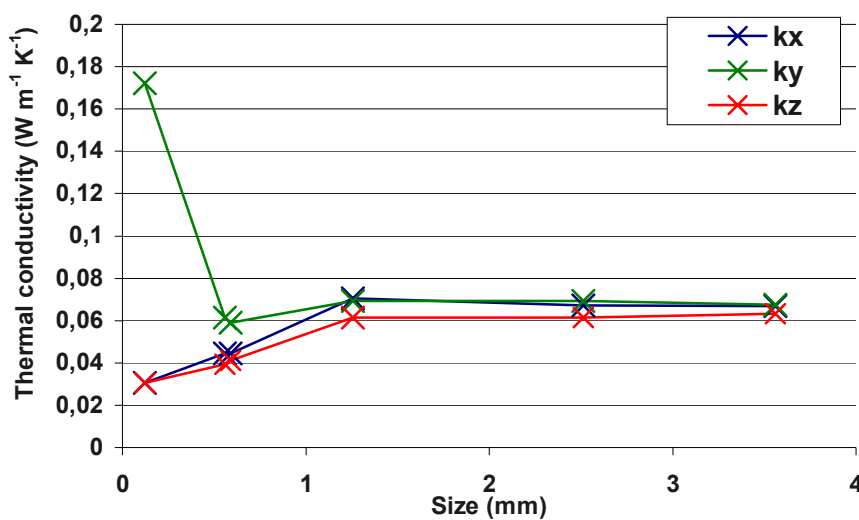


Figure 1.2: Dependency of k_{eff} estimates with sample size.

REV (mm)	2.5
Density (kg m^{-3})	124.9
k_x ($\text{W m}^{-1} \text{K}^{-1}$)	0.067
k_y ($\text{W m}^{-1} \text{K}^{-1}$)	0.067
k_z ($\text{W m}^{-1} \text{K}^{-1}$)	0.063

Table 1.1: Estimated REV, density and k_{eff} values.

Sample P04 - Decomposing and Fragmented precipitation particles (DF)

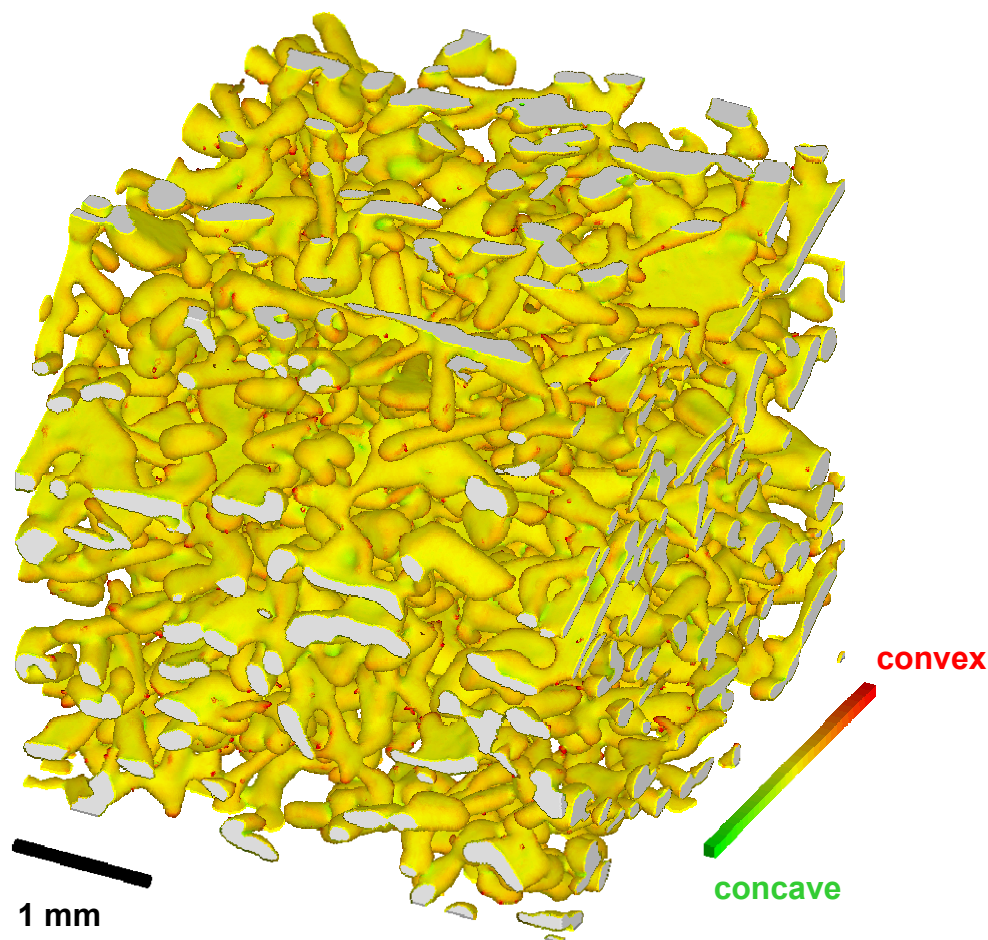


Figure 2.1: 3D visualization of the microtomographic image (size = 512^3 voxels, 1 vox. = $8.588 \mu\text{m}$).

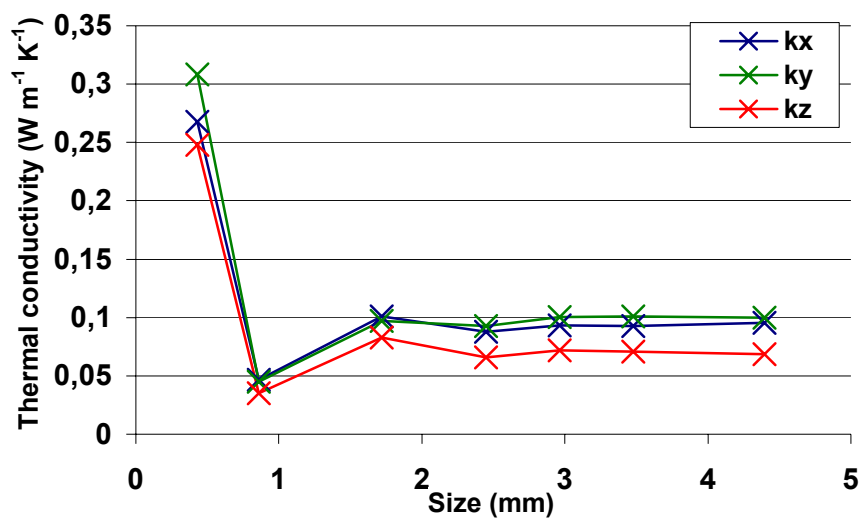


Figure 2.2: Dependency of k_{eff} estimates with sample size.

REV (mm)	3
Density (kg m^{-3})	157.6
k_x ($\text{W m}^{-1} \text{K}^{-1}$)	0.095
k_y ($\text{W m}^{-1} \text{K}^{-1}$)	0.100
k_z ($\text{W m}^{-1} \text{K}^{-1}$)	0.068

Table 2.1: Estimated REV, density and k_{eff} values.

Sample P11 - Rounded Grains (RG)

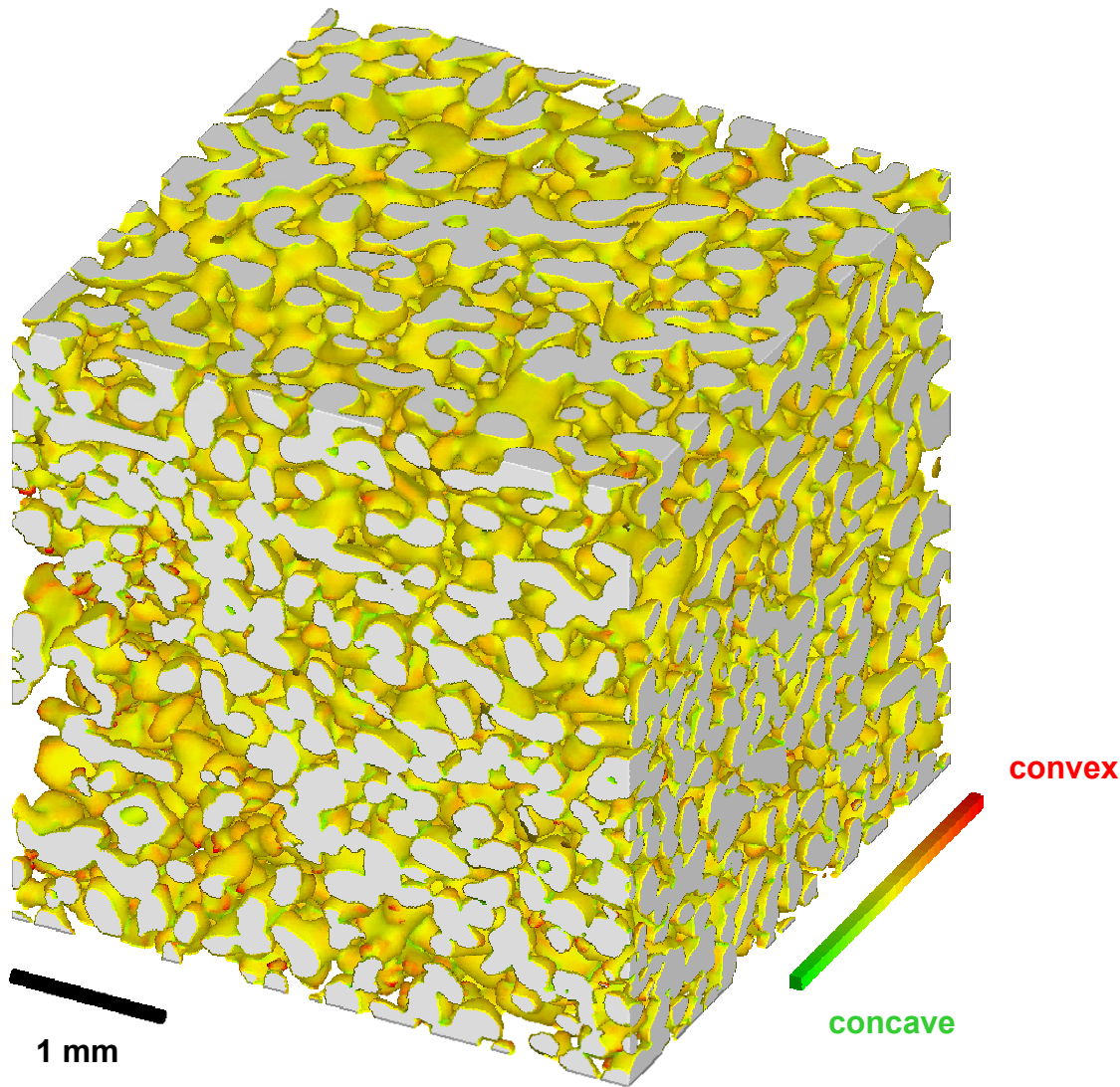


Figure 3.1: 3D visualization of the microtomographic image (size = 512^3 voxels, 1 vox. = $8.588 \mu\text{m}$).

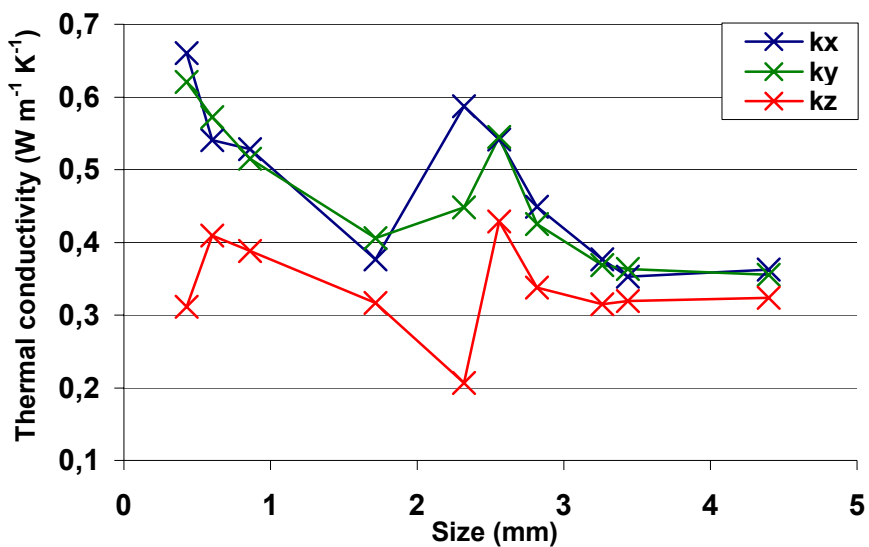


Figure 3.2: Dependency of k_{eff} estimates with sample size.

REV (mm)	4
Density (kg m^{-3})	413.7
k_x ($\text{W m}^{-1} \text{K}^{-1}$)	0.363
k_y ($\text{W m}^{-1} \text{K}^{-1}$)	0.356
k_z ($\text{W m}^{-1} \text{K}^{-1}$)	0.324

Table 3.1: Estimated REV, density and k_{eff} values.

Sample H02 - Melt Forms (MF)

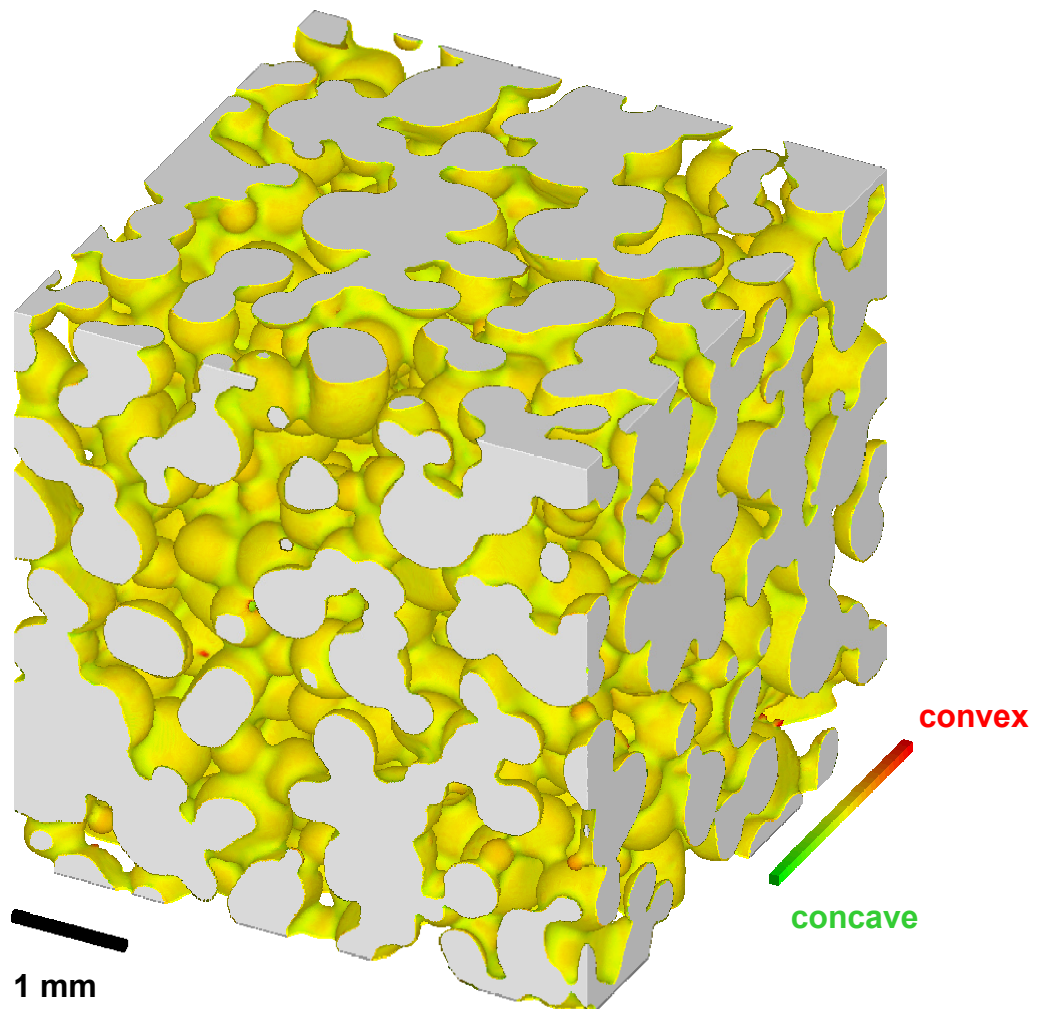


Figure 4.1: 3D visualization of the microtomographic image (size = 651^3 voxels, 1 vox. = 8.590 μm).

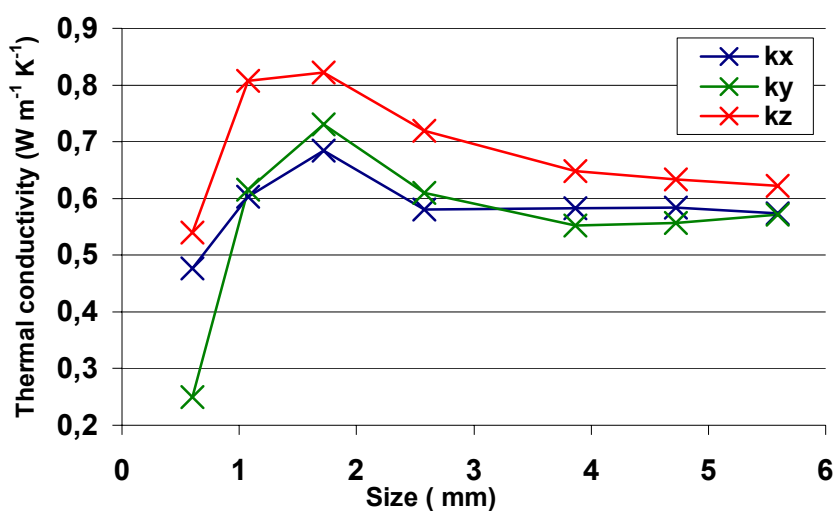


Figure 4.2: Dependency of k_{eff} estimates with sample size.

REV (mm)	5.5
Density (kg m^{-3})	502.6
k_x ($\text{W m}^{-1} \text{K}^{-1}$)	0.574
k_y ($\text{W m}^{-1} \text{K}^{-1}$)	0.571
k_z ($\text{W m}^{-1} \text{K}^{-1}$)	0.623

Table 4.1: Estimated REV, density and k_{eff} values.

Sample E2b – Faceted Crystals (FC)

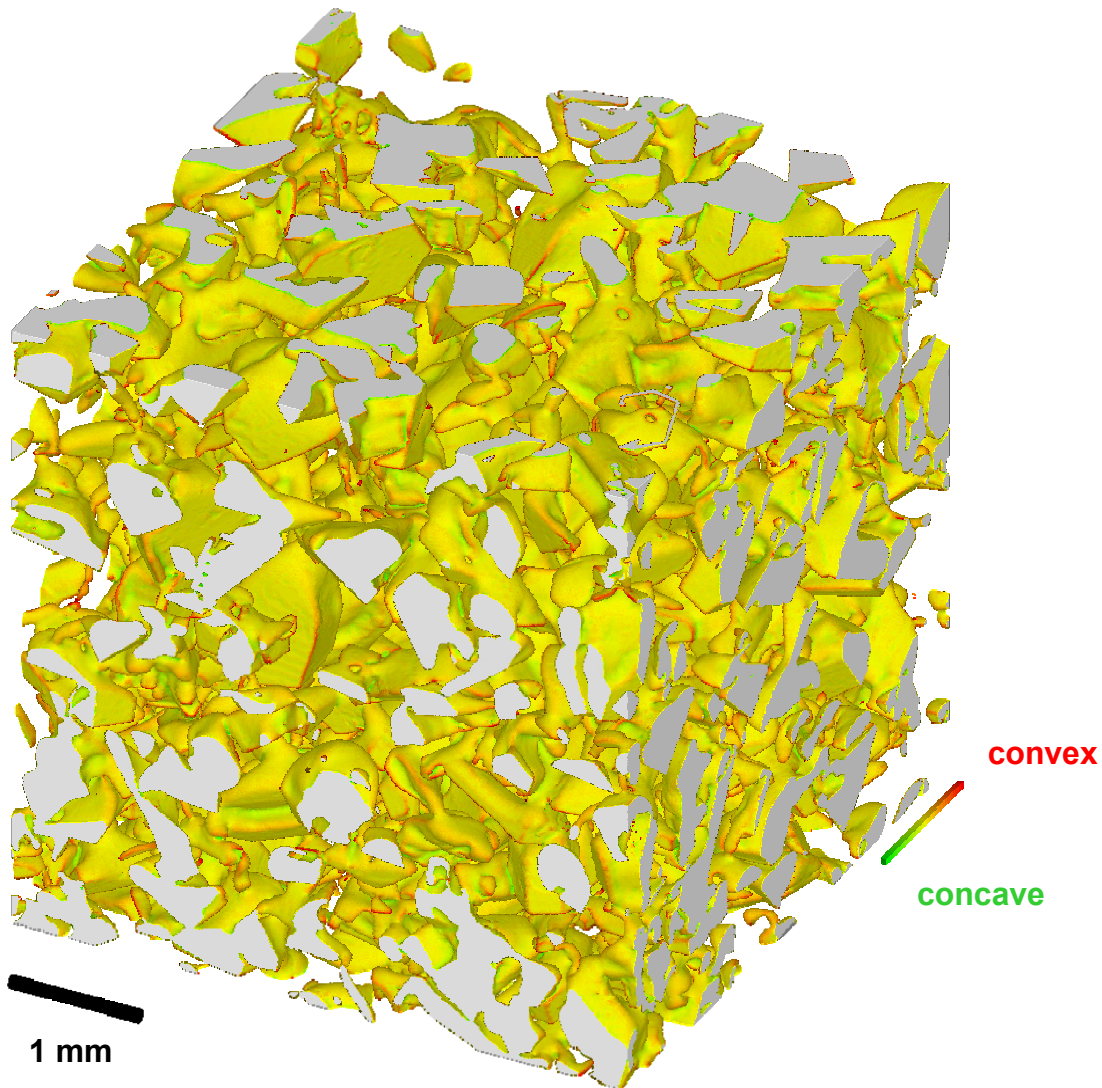


Figure 5.1: 3D visualization of the microtomographic image (size = 1200^3 voxels, 1 vox. = $4.91 \mu\text{m}$).

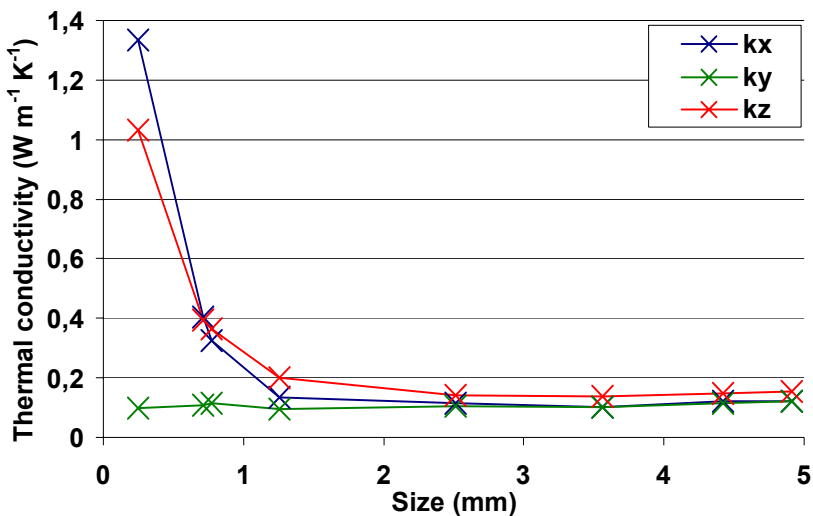


Figure 5.2: Dependency of k_{eff} estimates with sample size.

REV (mm)	3
Density (kg m^{-3})	262.7
k_x ($\text{W m}^{-1} \text{K}^{-1}$)	0.123
k_y ($\text{W m}^{-1} \text{K}^{-1}$)	0.121
k_z ($\text{W m}^{-1} \text{K}^{-1}$)	0.154

Table 5.1: Estimated REV, density and k_{eff} values.

Sample Grad3 – Depth Hoar (DH)

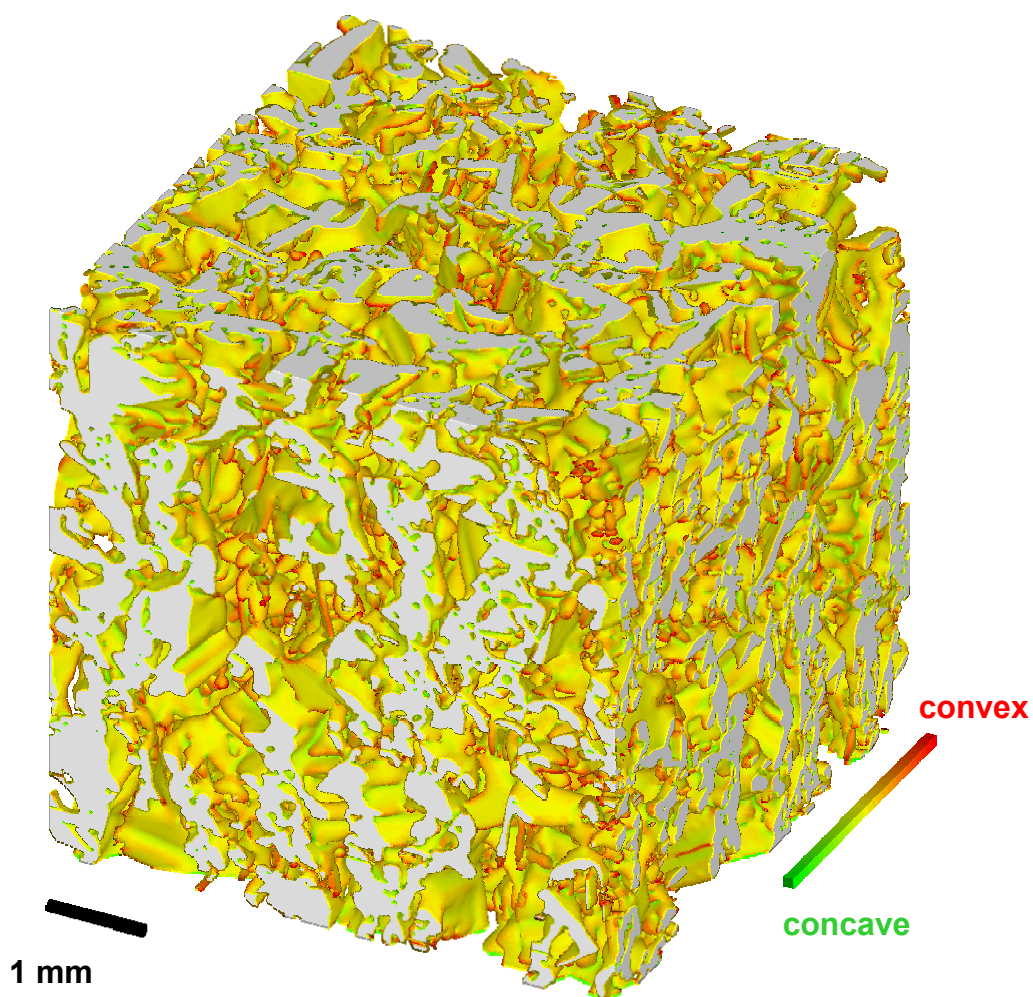


Figure 6.1: 3D visualization of the microtomographic image (size = 600^3 voxels, 1 vox. = 10 μm).

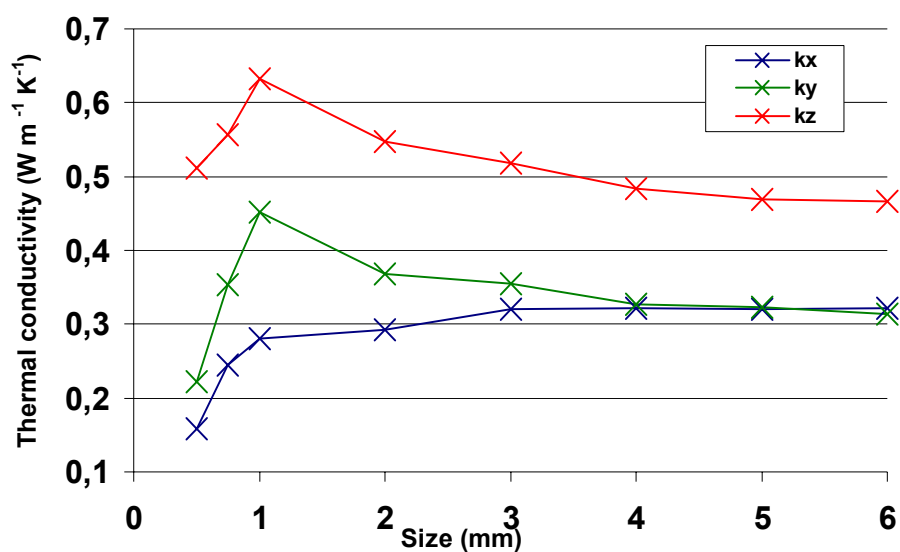


Figure 6.2: Dependency of k_{eff} estimates with sample size.

REV (mm)	5
Density (kg m^{-3})	369.2
k_x ($\text{W m}^{-1} \text{K}^{-1}$)	0.322
k_y ($\text{W m}^{-1} \text{K}^{-1}$)	0.314
k_z ($\text{W m}^{-1} \text{K}^{-1}$)	0.466

Table 6.1: Estimated REV, density and k_{eff} values.