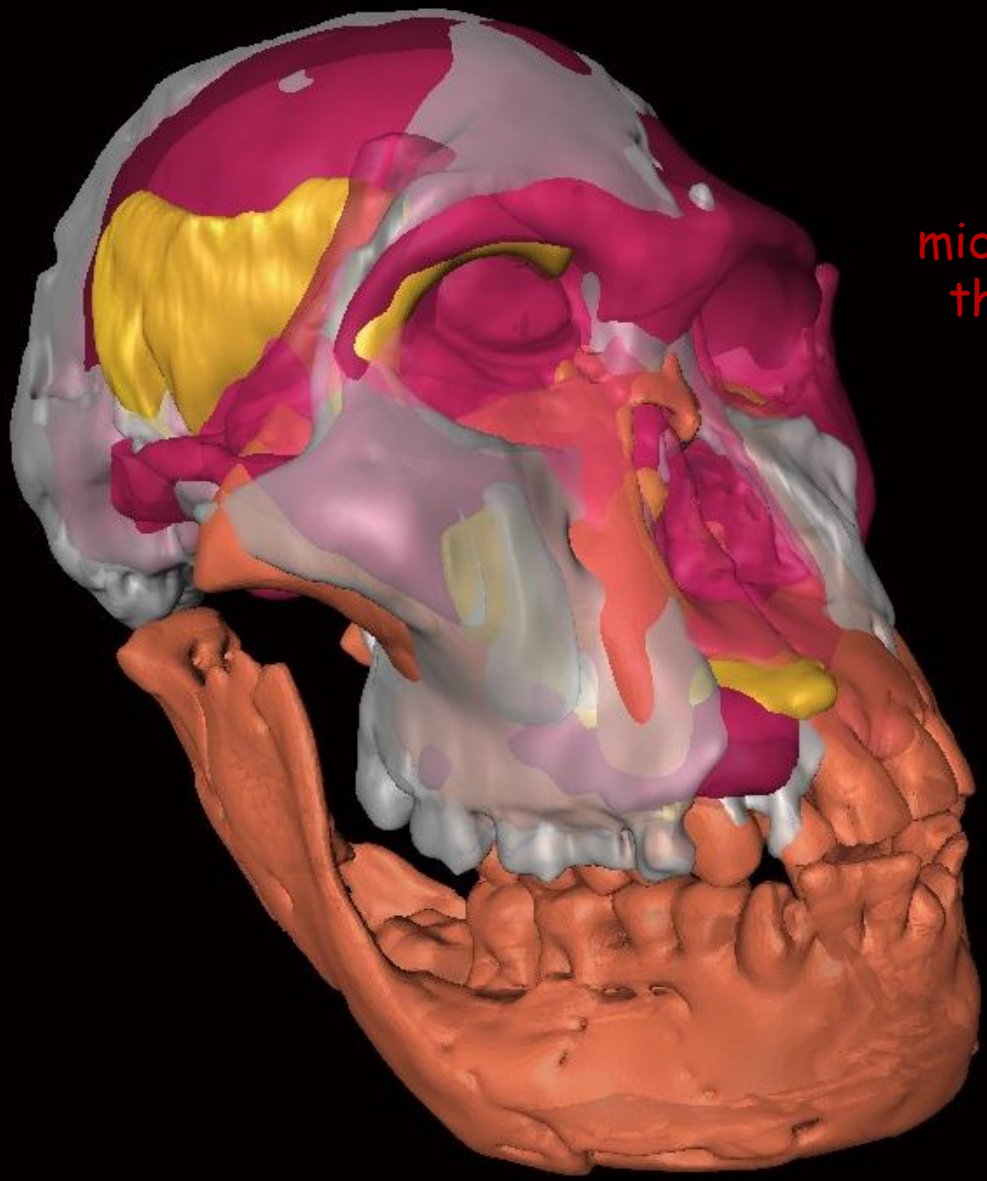

Evolution of Late Pliocene hominin midfacial morphology. An approach using three-dimensional surface registration

J. Braga[1,3], G. Subsol[2], F. Thackeray[3], G. Dasgupta[4], V. Balter[5,3], F. Dedouit[1], N. Telmon[1]

[1]Department of Biological Anthropology, University Paul Sabatier, Toulouse, France

[2]Department of Computer Science, LIRMM, University of Montpellier, France

[3]Human Origins and Past Environments Programme, Transvaal Museum, South Africa

[4]Department of Engineering Mechanics, Columbia University, U.S.A.

[5]Ecole Normale Supérieure, Lyon, France.

EVAN
setting landmarks in science

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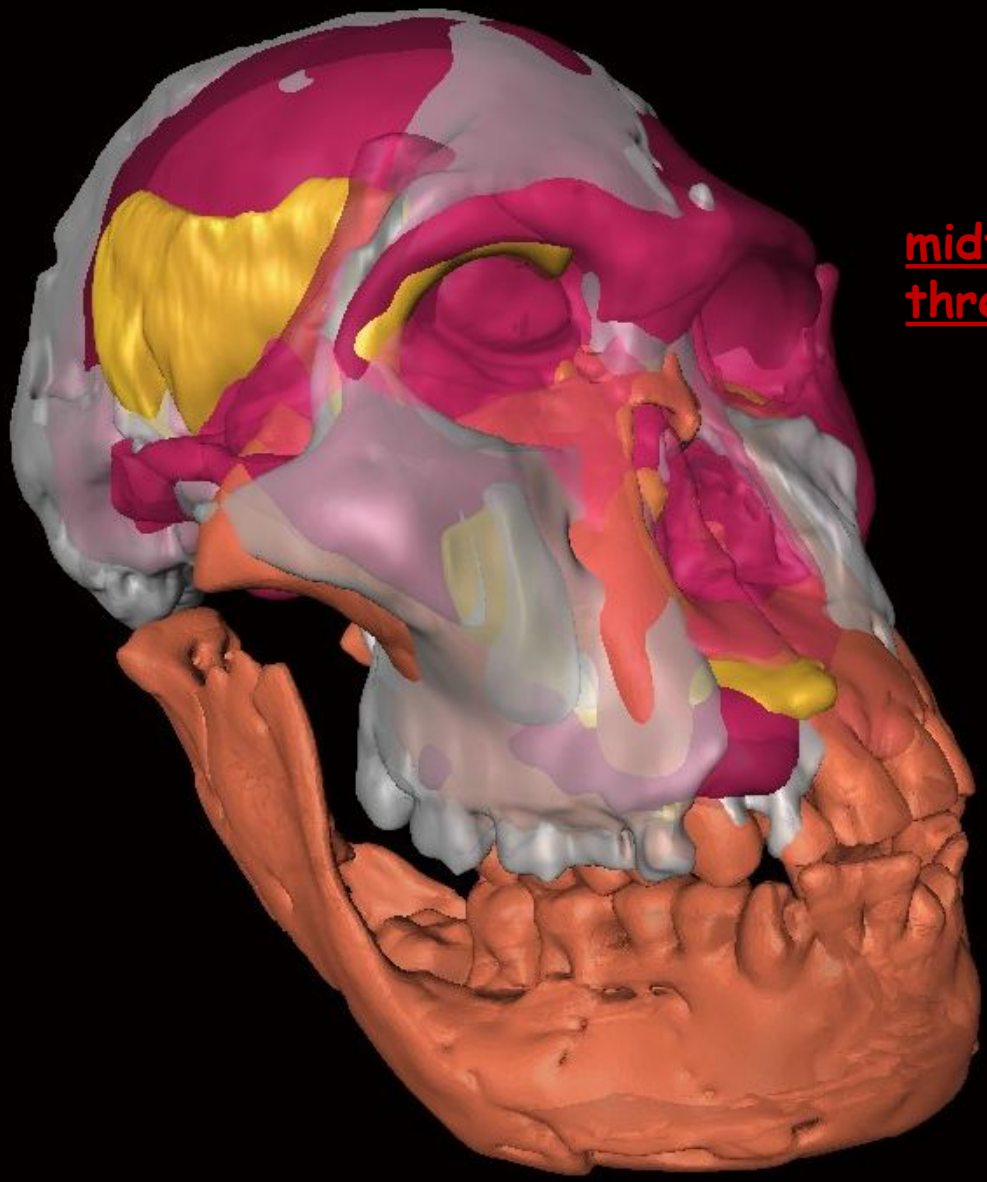
PEPS / ODENT



Evolution of Late Pliocene hominin **midfacial morphology**. An approach using **three-dimensional surface registration**.

J. Braga[1,3], G. Subsol[2], F. Thackeray[3], G. Dasgupta[4], V. Balter[5,3], F. Dedouit[1], N. Telmon[1]

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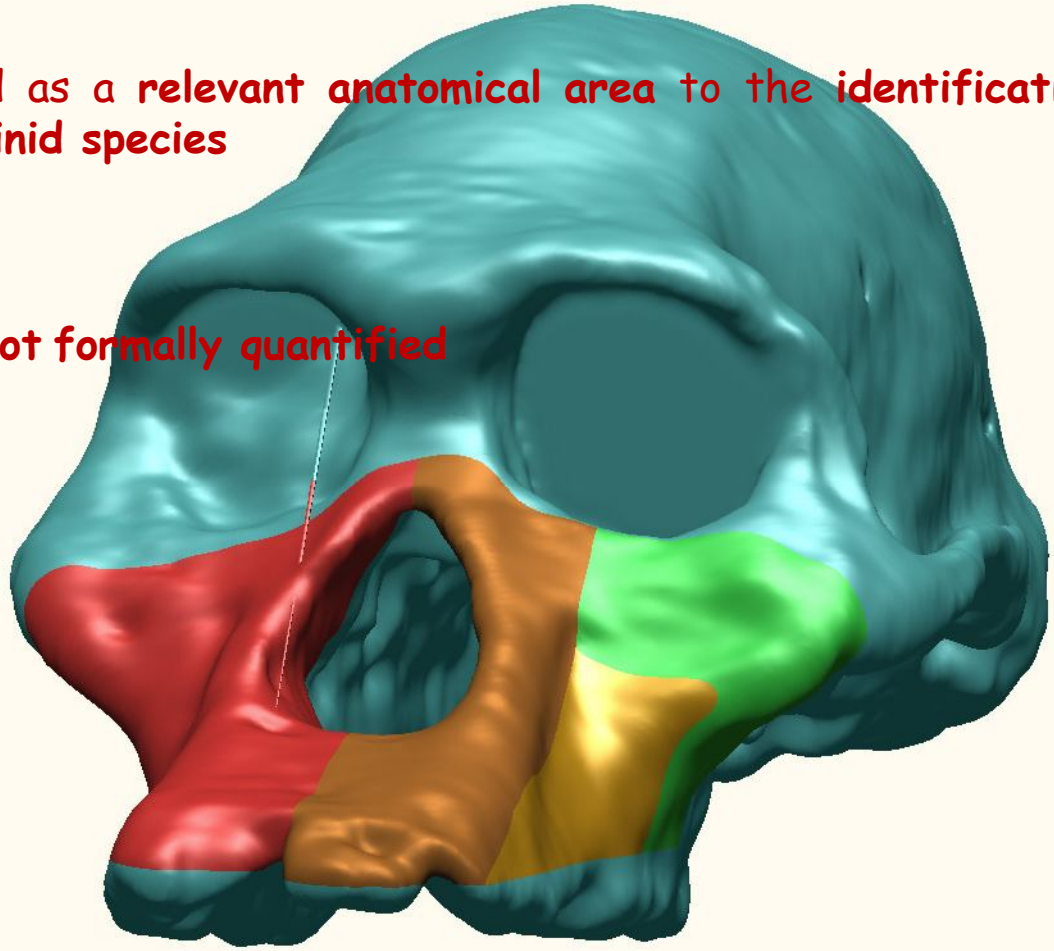
PEPS / ODENT

Form and **local anatomical changes** of the **mid-facial skeleton**

Considered as a **relevant anatomical area** to the **identification of extant and fossil hominid species**

So far : not formally quantified



Current methods

• Visual inspection
(Rak, 1983, 1985; Braga, 1996, 1998; McCollum and Ward, 1997; Lockwood, 1999)

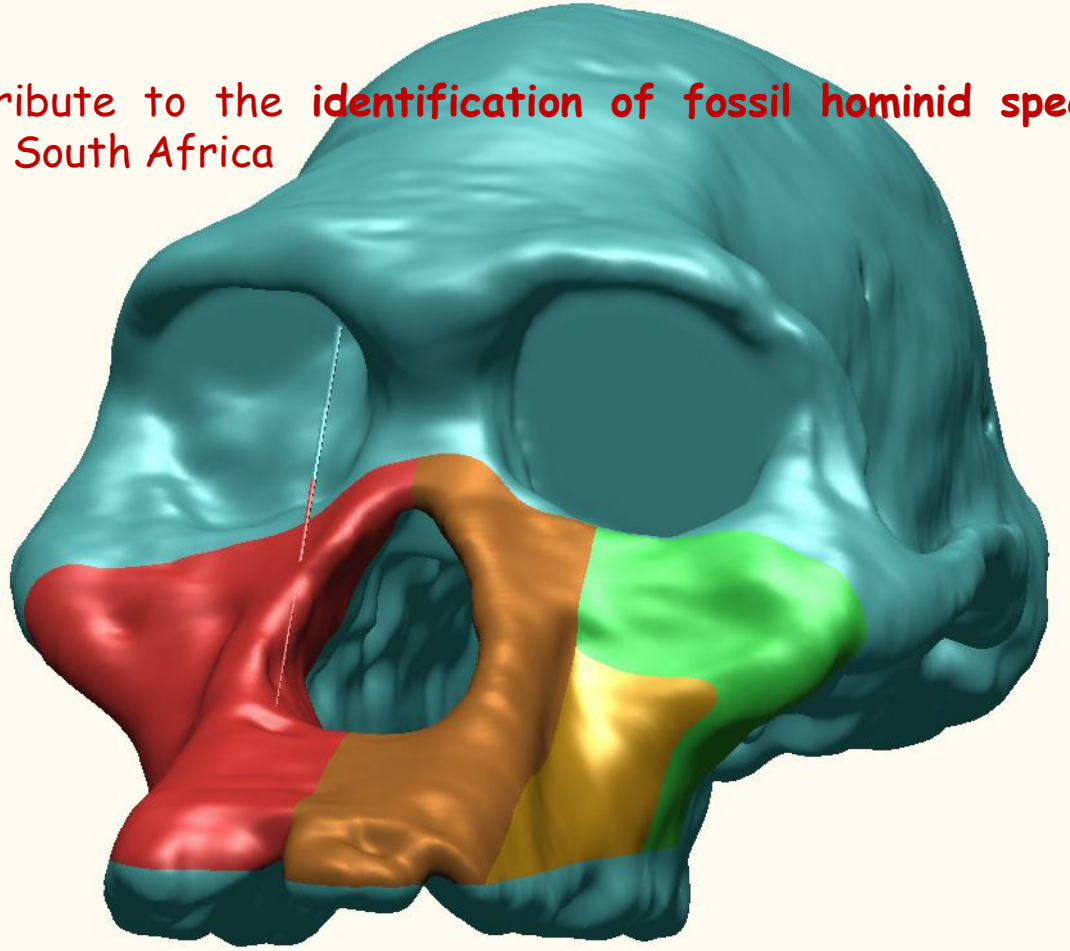
• Linear and angular measurements
(Lockwood, 1999; Leakey et al., 2001)

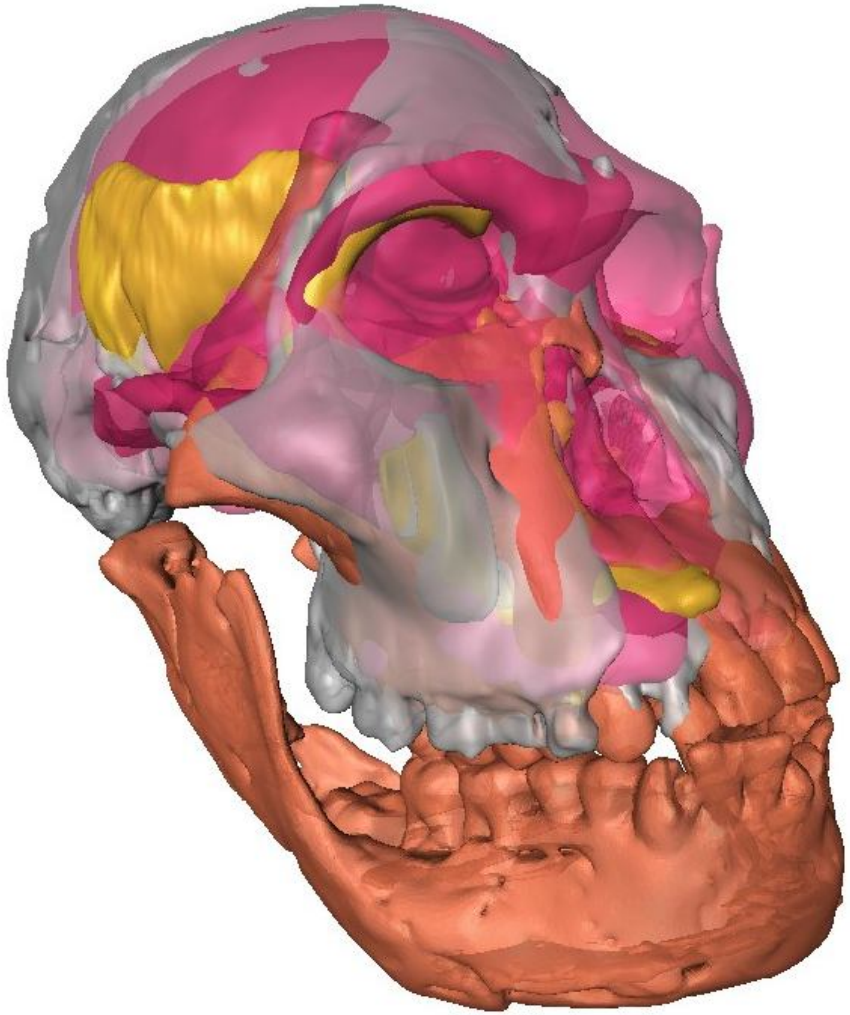
• 3 D GMM : Landmark and/or semi-landmark based methods
(Ponce de Leon and Zollikofer, 2001; Cobb and O'Higgins, 2004)

- **Introduce automatic methods**
- **Propose a protocol**

for the study of **local anatomical changes** of the **mid-facial skeleton**

Aim: Contribute to the **identification of fossil hominid species** in the late Pliocene of South Africa





What do we need?

Use **automatic methods of comparison** which do not depend on the prior manual selection of specific landmarks or curves (definition, accuracy, reproducibility, time-consuming)

Describe **shape differences** with **precise anatomical, geometrical features**, rather than fuzzy terms

Detect **local shape changes**

Detect possible **allometric changes** (size changes possibly correlated with shape changes)

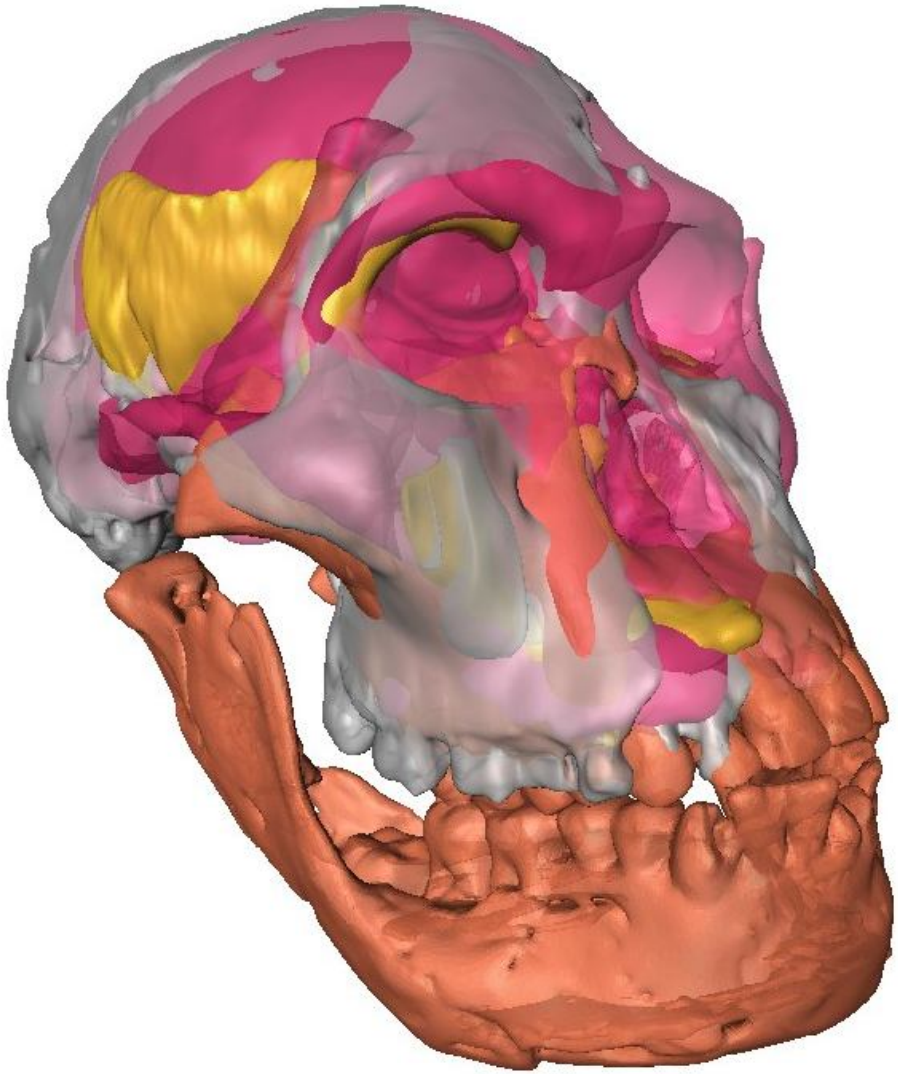
Why local shape changes are so important?

An example : the nasal spine in *Pan paniscus*

Tableau Fréquences observées et proportions calculées pour l'insertion antérieure du septum nasal.
Observed frequencies and calculated proportions for the anterior attachment of the nasal septum.

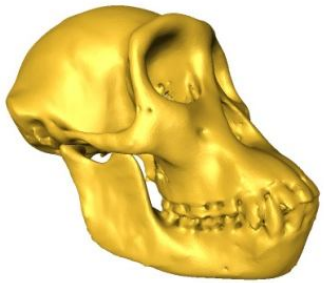
	Enfants		Juvéniles		Adultes	
	%	n/N	%	n/N	%	n/N
P. t. verus	0	0/2	0	0/13	3	3/100
P. t. troglodytes	0	0/20	4,7	3/64	9,4	13/139
P. t. schweinfurthi	0	0/20	1,5	1/68	9,6	11/115
P. paniscus	18,2	4/22	43,6	34/78	76,1	51/67
G. g. gorilla	0	0/19	1,7	1/60	12,3	19/155
G. g. graueri	0	0/8	4,3	1/23	61,3	46/75
G. g. beringei	0	0/3	0	0/15	29,7	11/37

Apply both methods and protocol to Pliocene hominids from South Africa and propose preliminary interpretations



Comparative samples: *Pan troglodytes*

5 females



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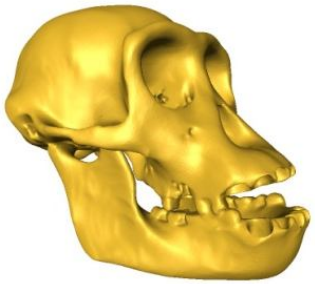

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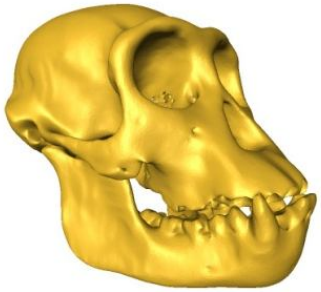

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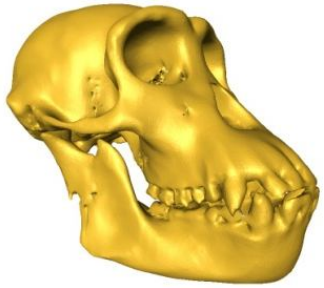
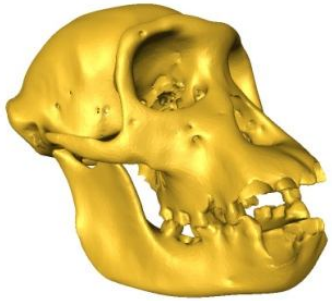


A1_F_MCZ_7286

A1_F_MCZ_7265

5 males



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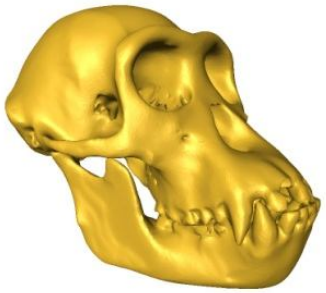

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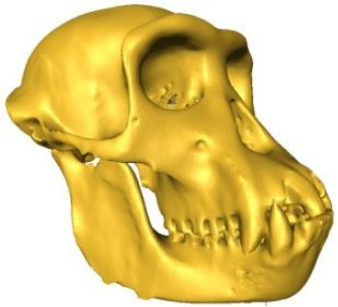

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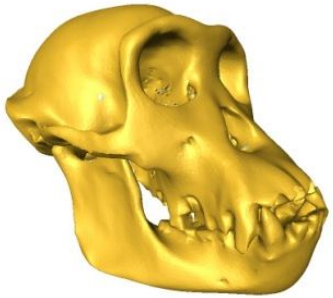

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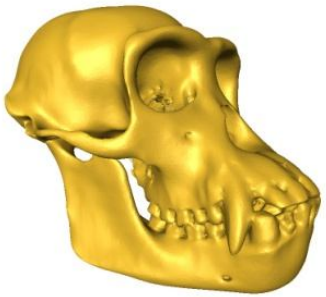
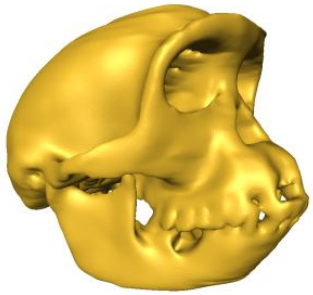


A2_M_MCZ_6923

Comparative samples : *Pan paniscus*

5 females

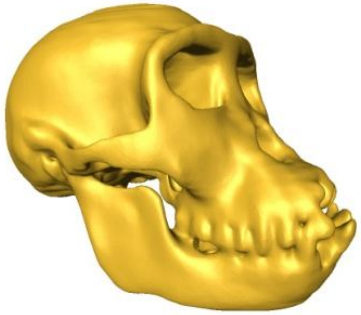


A2_F_MRAC_9338

A2_F_MRAC_11351

A2_F_MRAC_11352

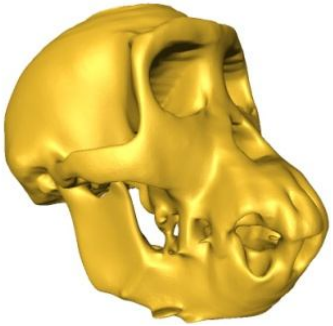
A2_F_MRAC_29060



A2_F_MRAC_29065

5 males

A2_M_MRAC_15294



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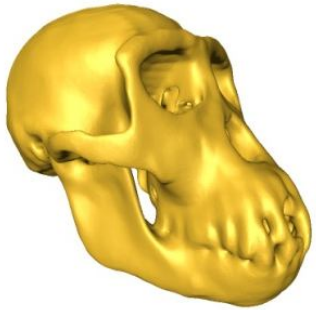

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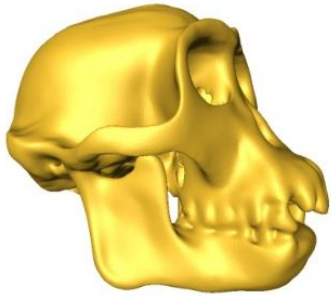

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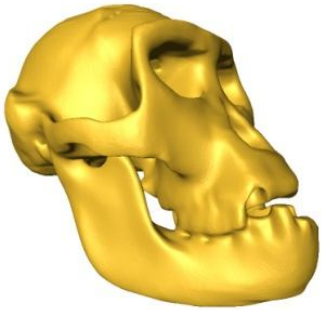
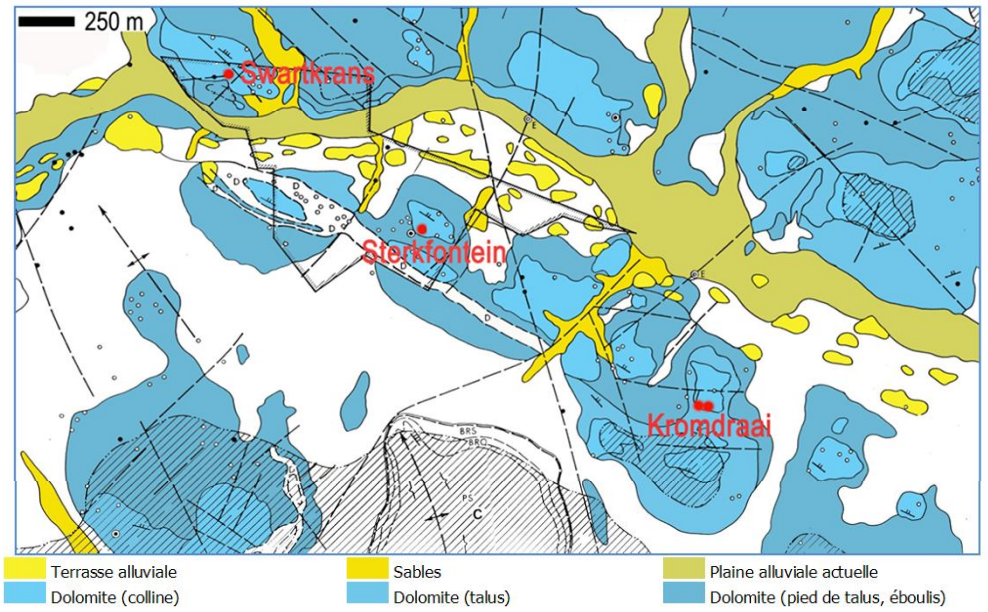


A2_M_MRAC_29064

The Craddle of Humankind World Heritage Site - South Africa



Sterkfontein
Member 4
(2,14 – 2.15 Ma ?)

?

Kromdraai B
Member 3 (1,95 – 2,42 Ma ?)

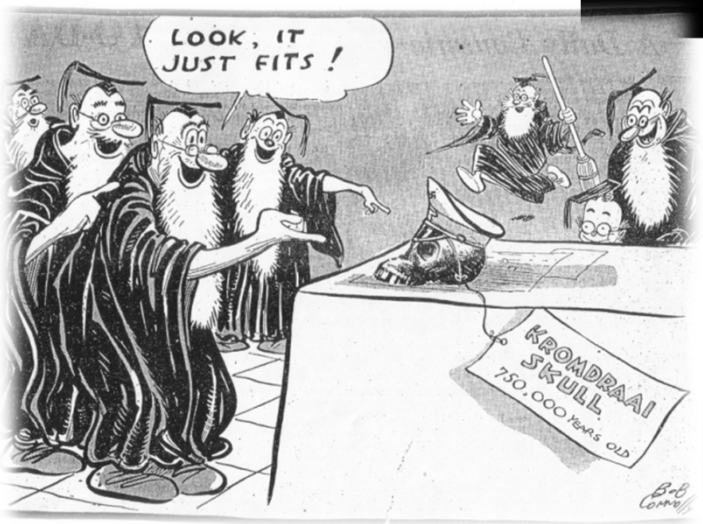
Kromdraai B
Member 1 (1,95 – 2,42 Ma ?)

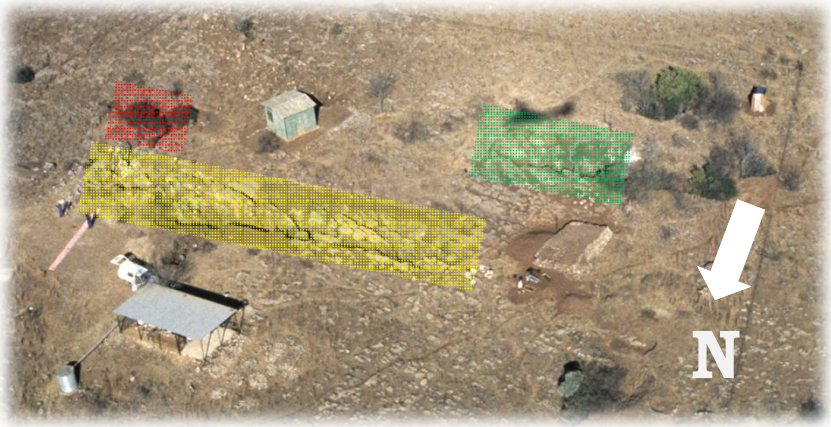
Sterkfontein Member 4

Sts 5
Sts 52
Sts 71
Sts 17
TM 1511
TM 1512

Kromdraai B Member 1

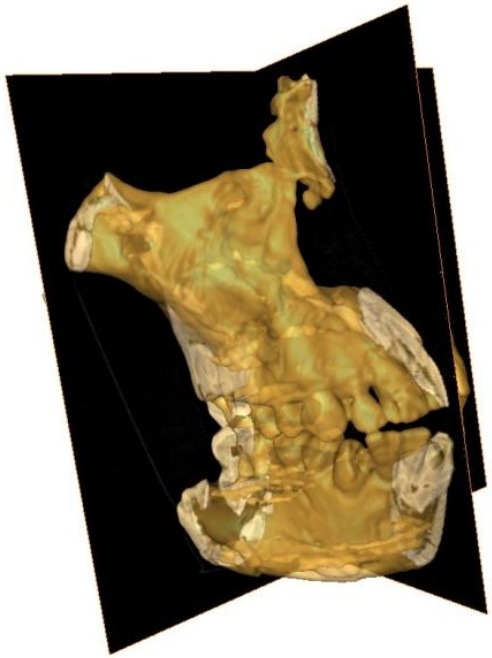
TM 1517





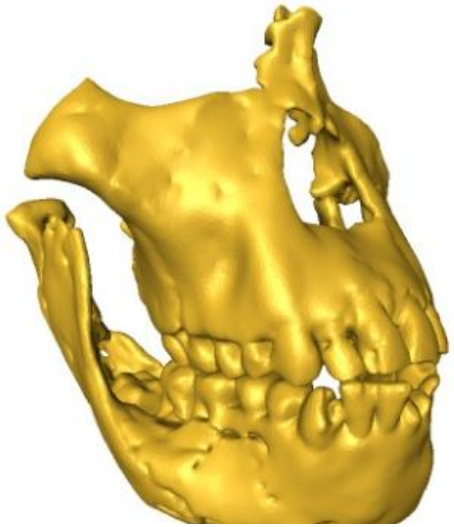
1. Pre-process 3D data

for all samples (comparative & fossils)



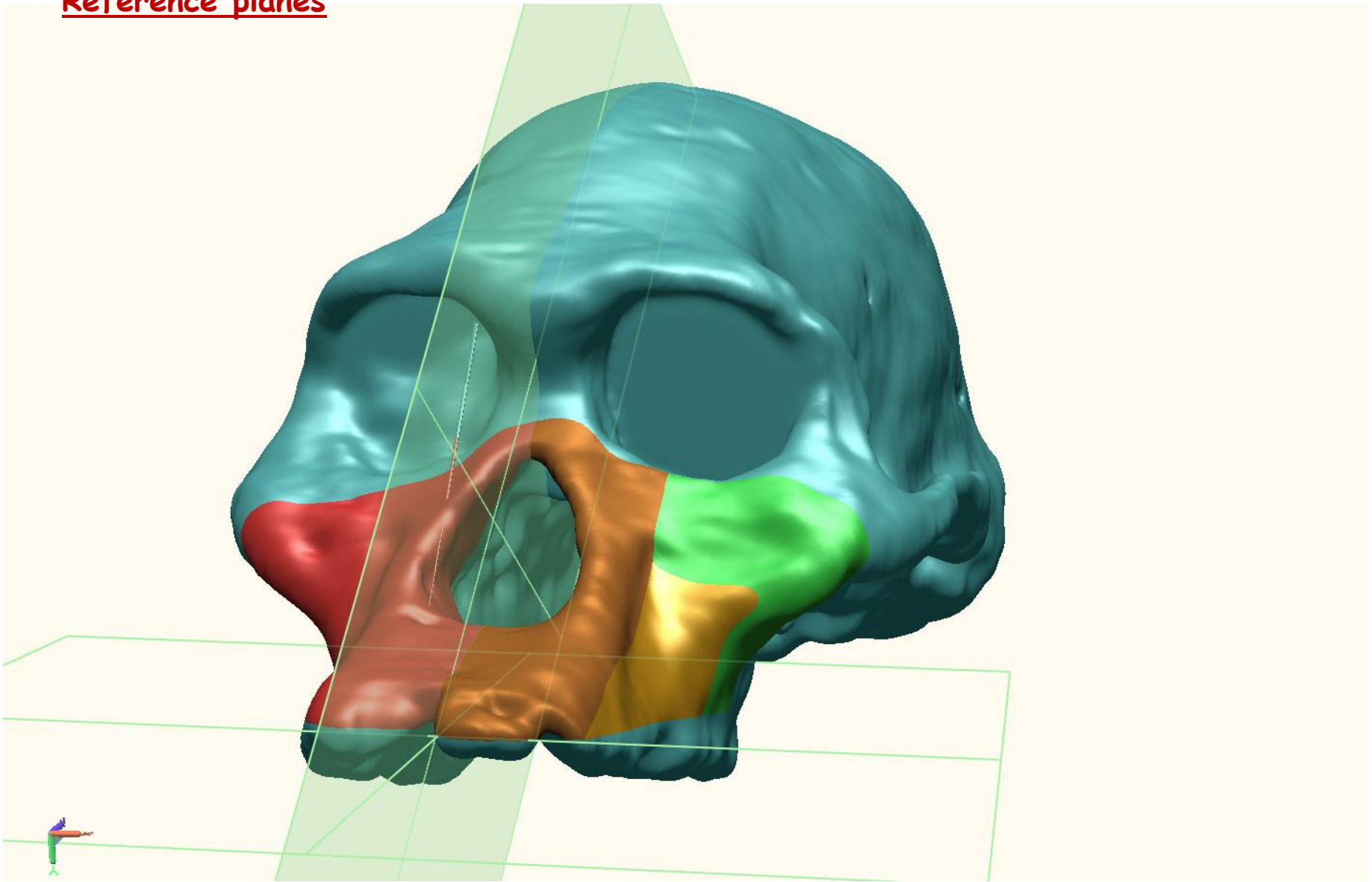
Computed Tomography data
(resolution ~ 0.1mm)

Surface data as a 3D mesh

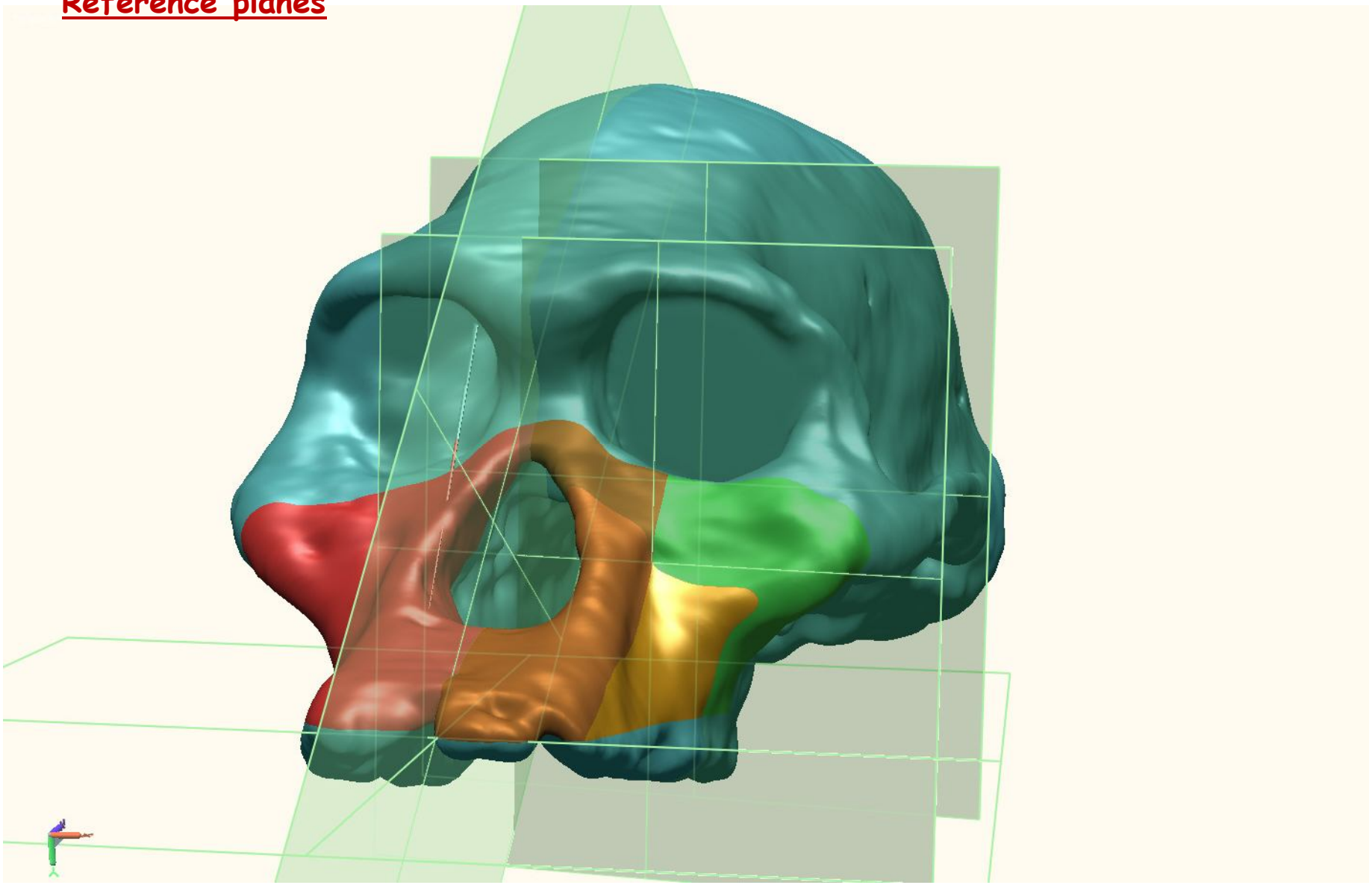


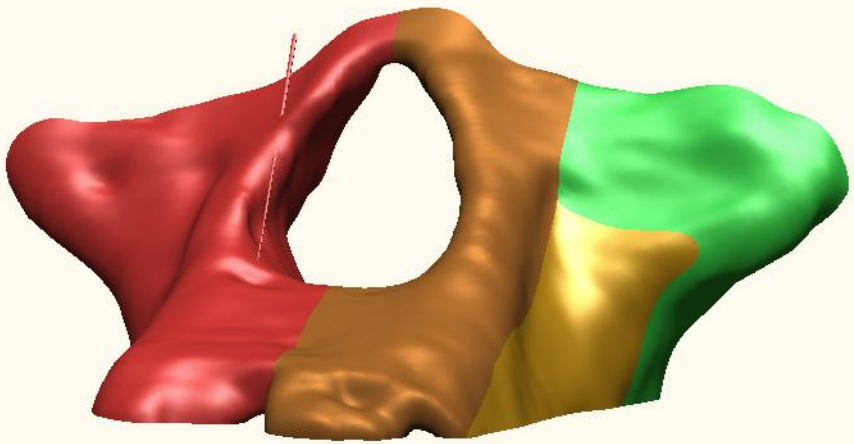
Example: STS_52
(201,013 vertices / 402,433 faces)

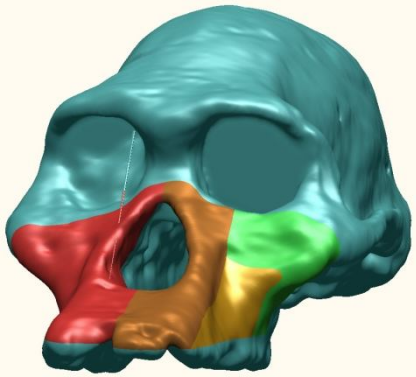
Reference planes

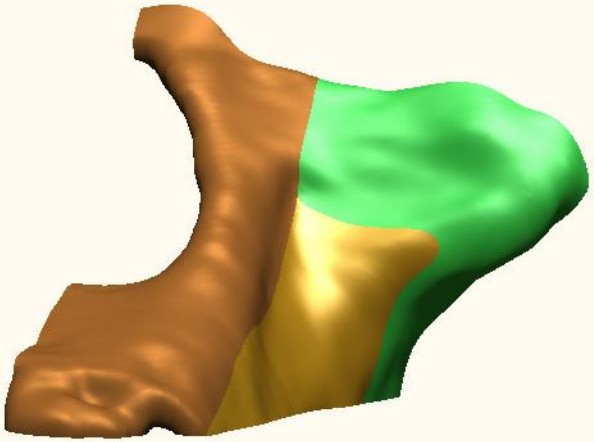


Reference planes

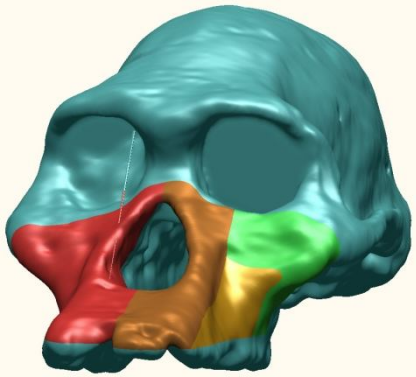






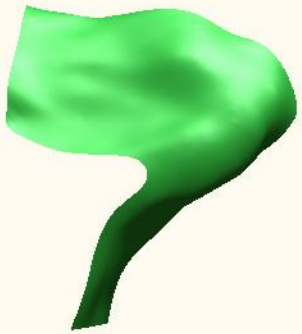


Location of the most anterior origin of the zygomatic process on the maxilla



Sts 5 and Sts 52 display an extreme variation in this regard.

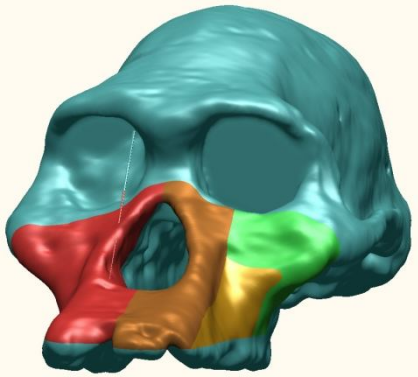
The zygomatic process of Sts 5 is located much more posterior than in Sts 52

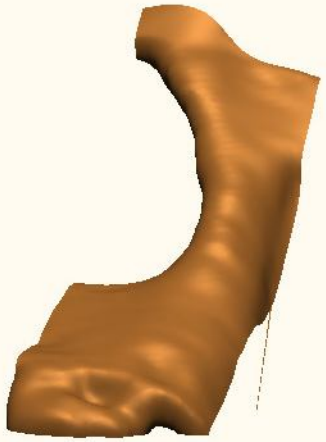


Form of the "anterior pillar" (sensu Rak, 1983)

A "column" of bone that forms the rounded margin of the nasal aperture and runs alongside the nasoalveolar clivus in some specimens

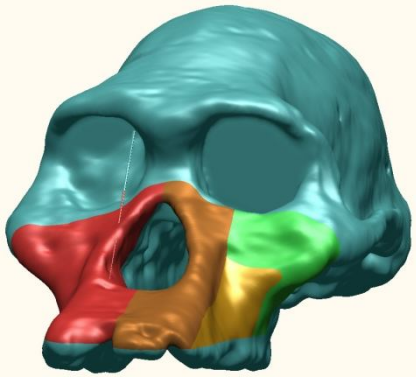
Defined laterally by a maxillary furrow and independent of the "canine jugum"

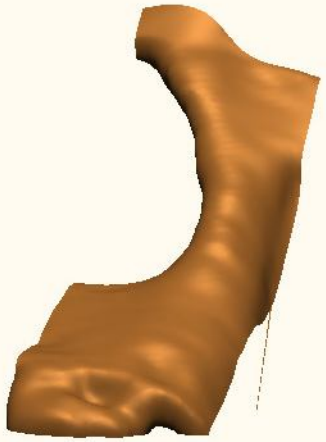




Rak (1983) hypothesized sexual dimorphism in the form of the anterior pillar in *A. africanus*

Rak (1983) : one of the derived features linking *A. africanus* and *A. robustus.*
"The presence of anterior pillars in the face of [*A. africanus*] places it clearly in the robust australopithecine clade,"

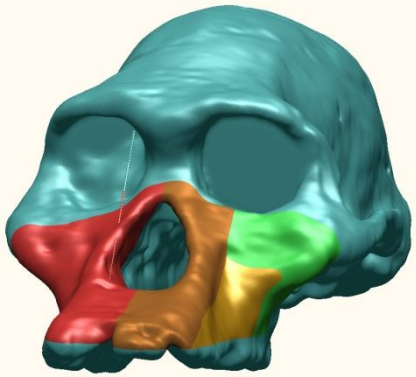


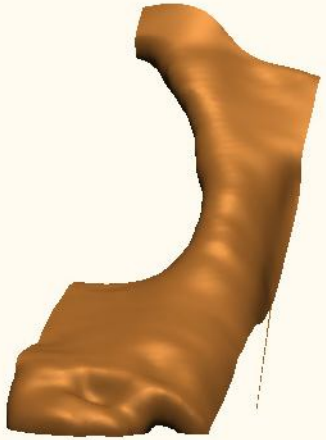


Topography and orientation of the nasoalveolar clivus

The outer surface of the portion of the facial skeleton bearing the upper incisors (incisive bone)

Also includes the most anterior part of the nasal floor and its transition with the incisive bone.

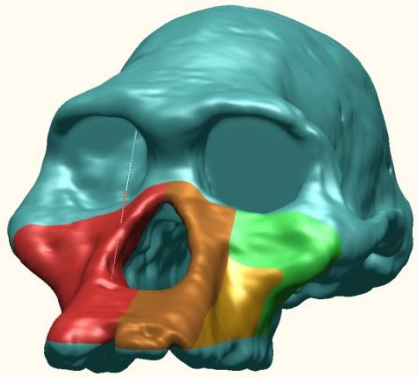




Concavity of the anterior surface of the infraorbital region

Surface lying between the anterior pillar (medially) and zygomatic process (laterally)

In addition to its overall topography, the infraorbital region can also be described by the presence of a canine fossa



Is variation in form within the Sterkfontein sample, within SA Pliocene hominids, greater than expected for weakly dimorphic species such as chimpanzees or bonobos?

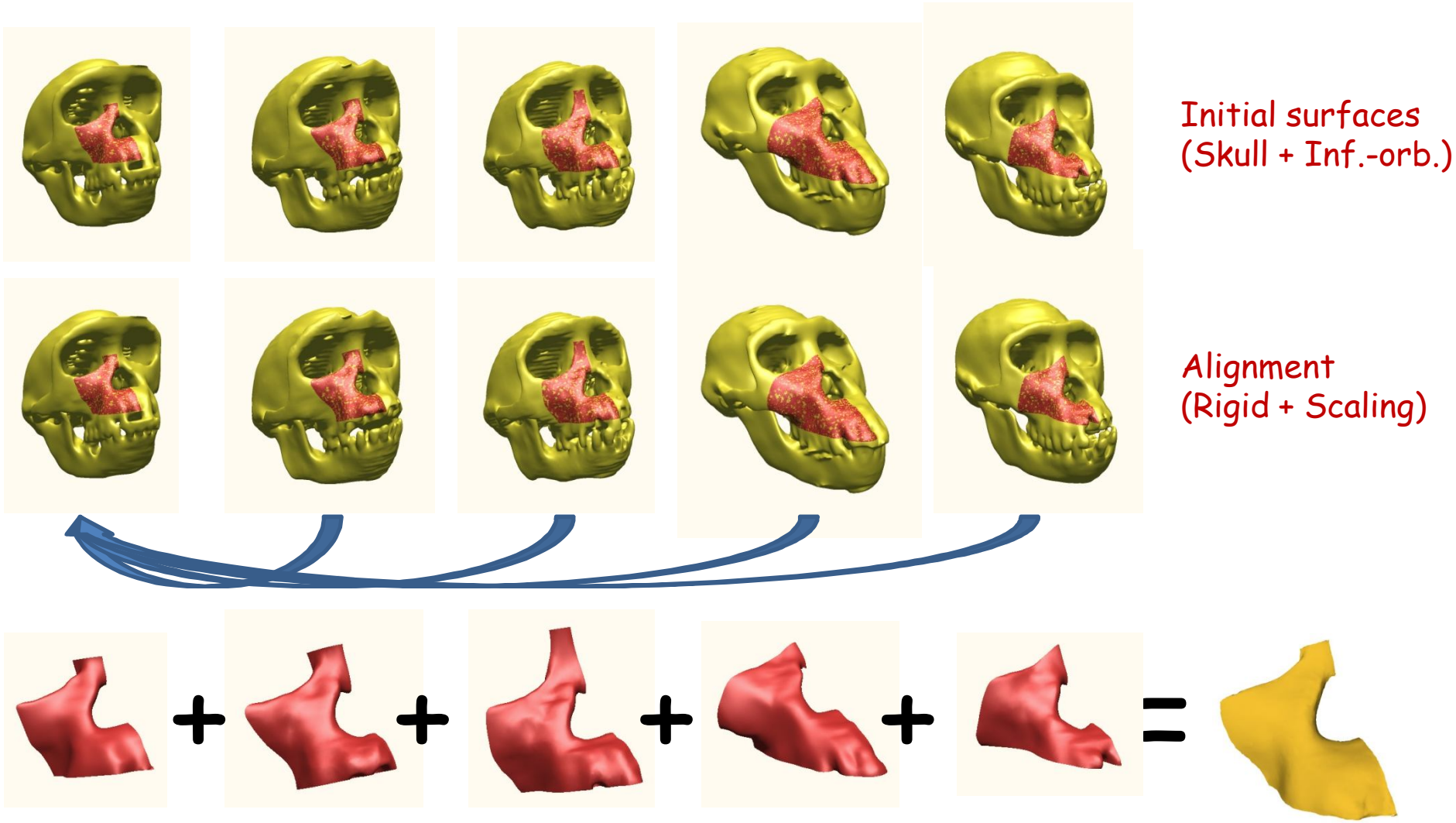
⇒ Reference maps

5 bonobo females

2. Compute reference maps

Initial surfaces

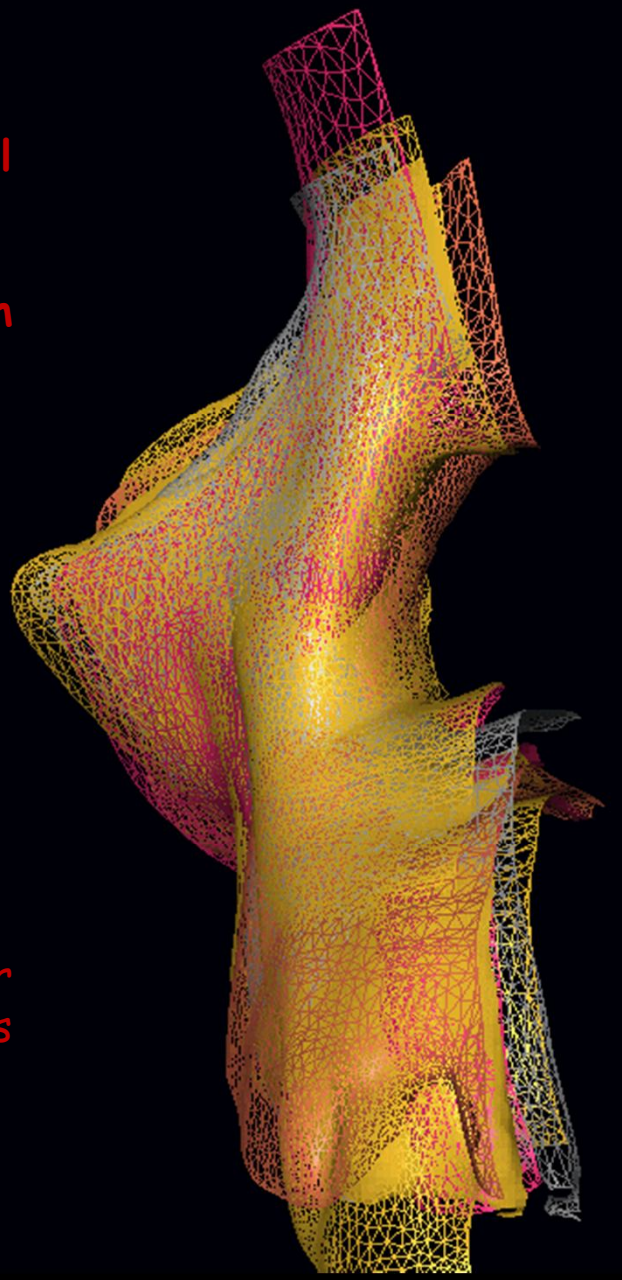
5 bonobo females



Calculation of a mean surface model
based on vertex-to-vertex correspondences

"True" mean surface model based on all the vertices.

Not a mean shape extrapolated from landmarks.

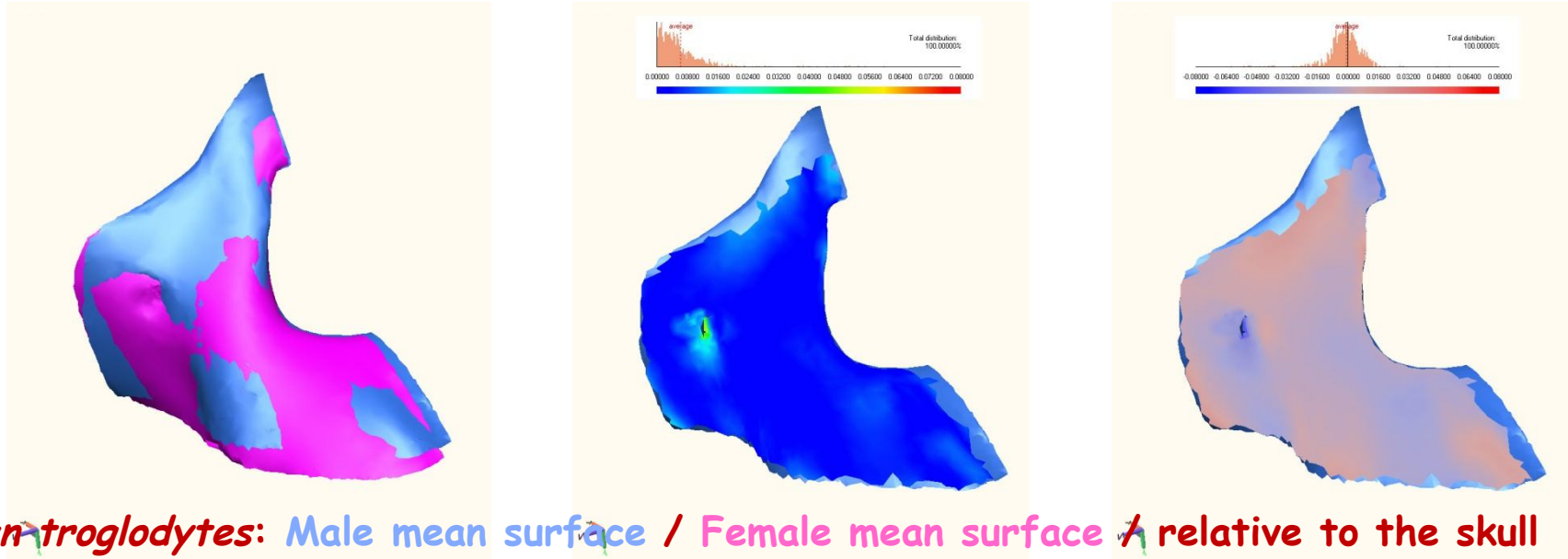


Example : mean surface model from our sample of 5 bonobo females (2,866 vertices / 5,222 faces)

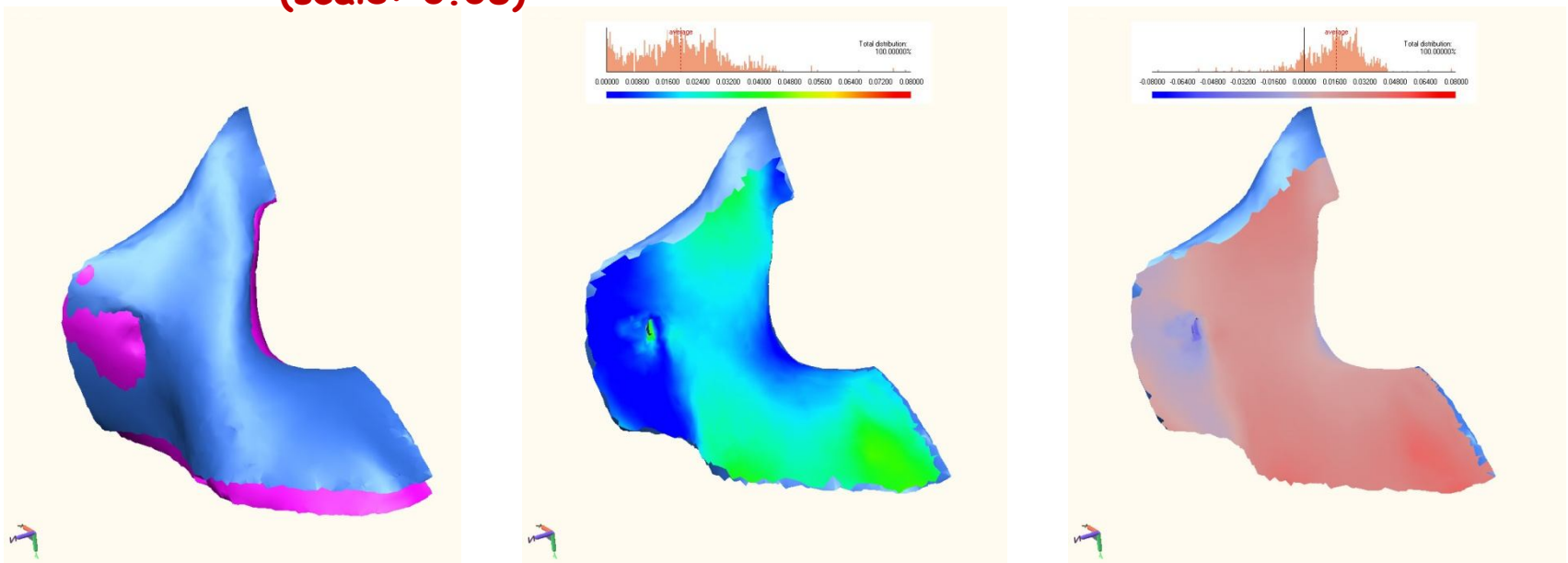
Entirely automatic process.

Time ~ 1mn

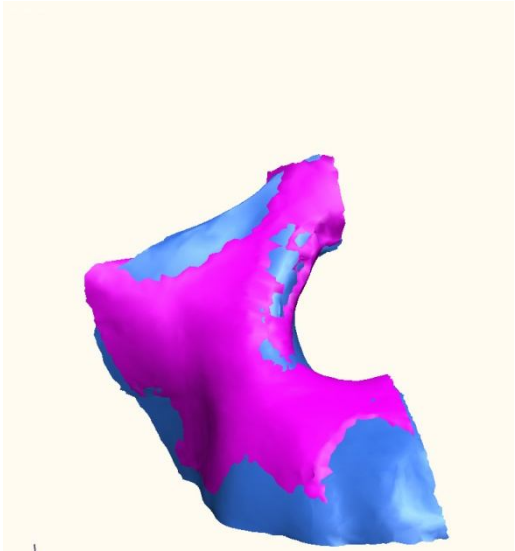
***Pan troglodytes*: Male mean surface / Female mean surface (scale: 0.08)**

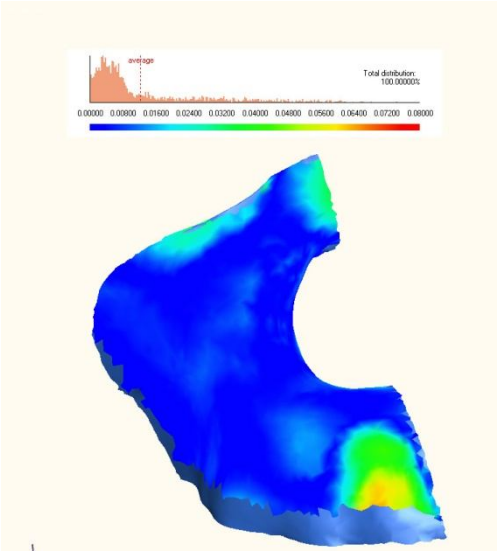


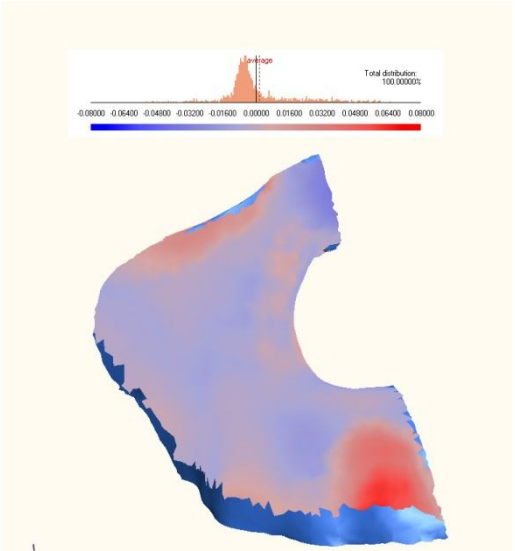
***Pan troglodytes*: Male mean surface / Female mean surface / relative to the skull (scale: 0.08)**



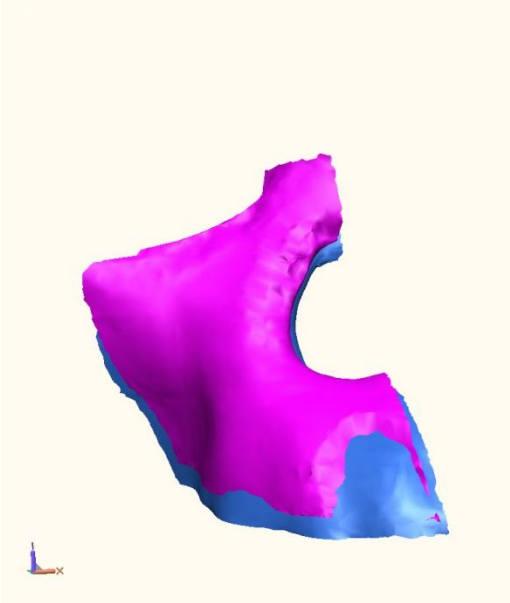
Pan paniscus : Male mean surface / Female mean surface (scale: 0.08)

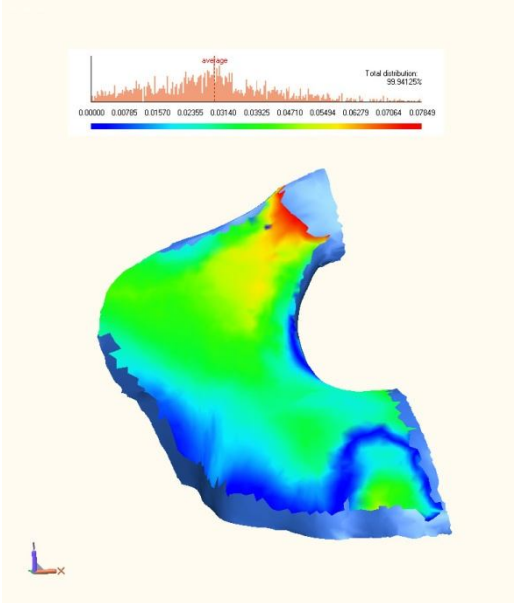


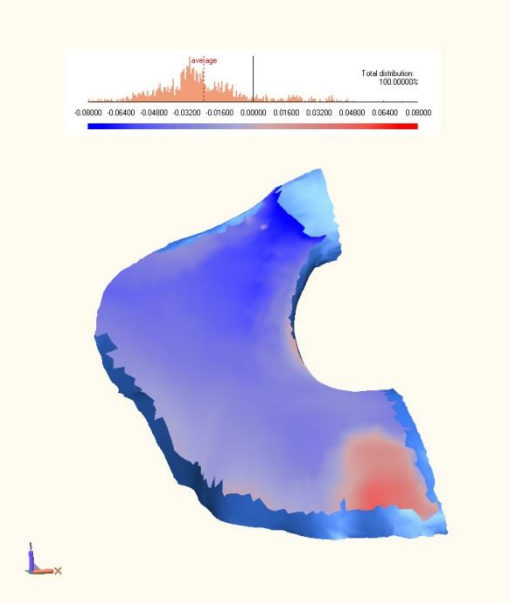




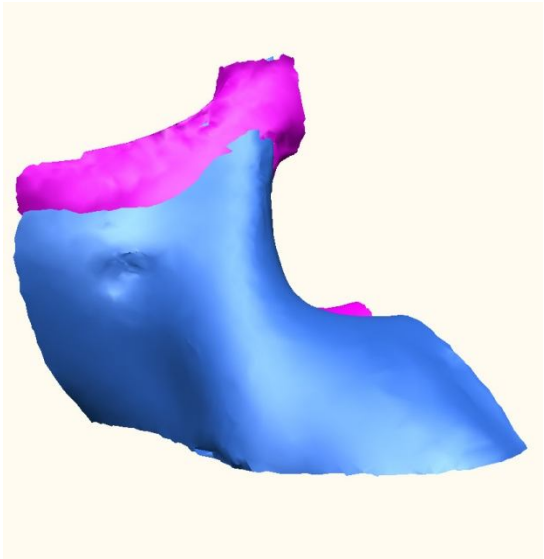
Pan paniscus : Male mean surface / Female mean surface / relative to the skull (scale: 0.08)

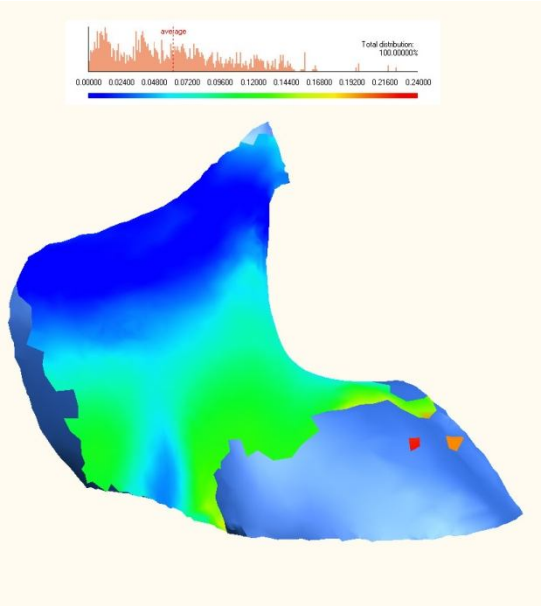


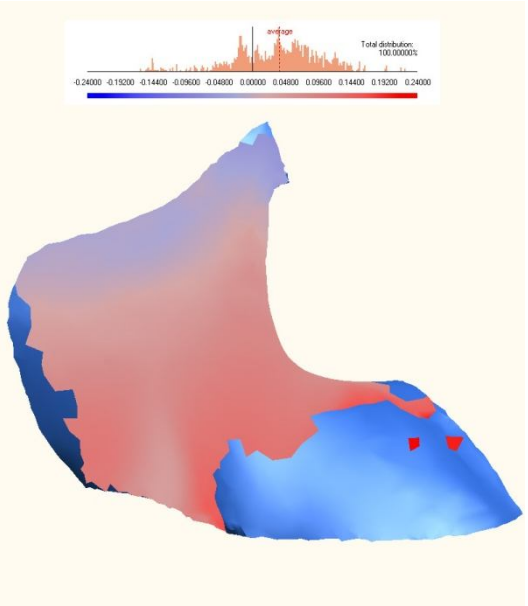




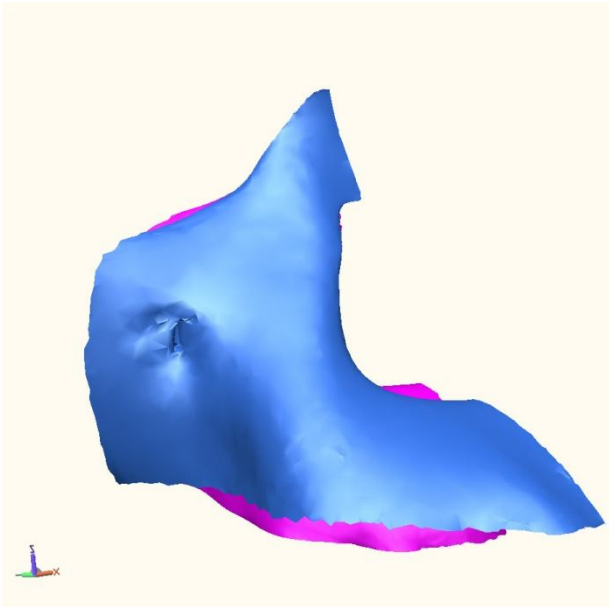
Females : *P. troglodytes* mean surface / *P. paniscus* mean surface (scale: 0.24)

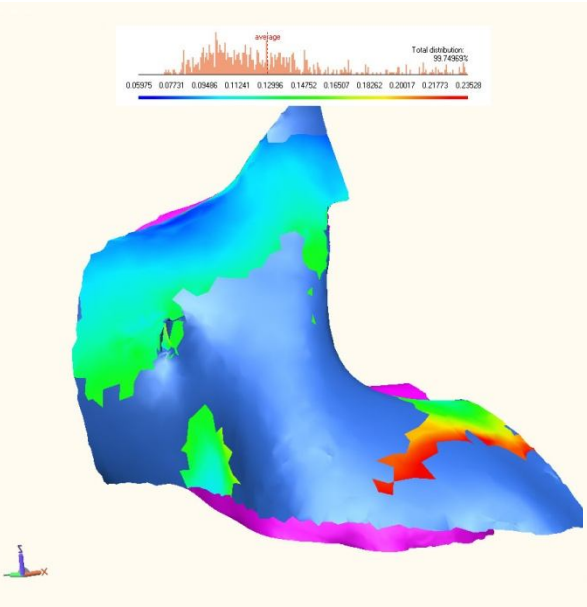


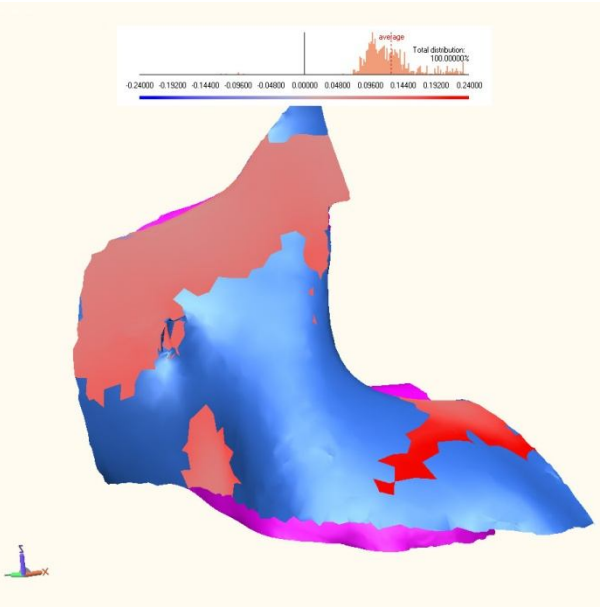




Males : *P. troglodytes mean surface* / *P. paniscus mean surface* (scale: 0.24)







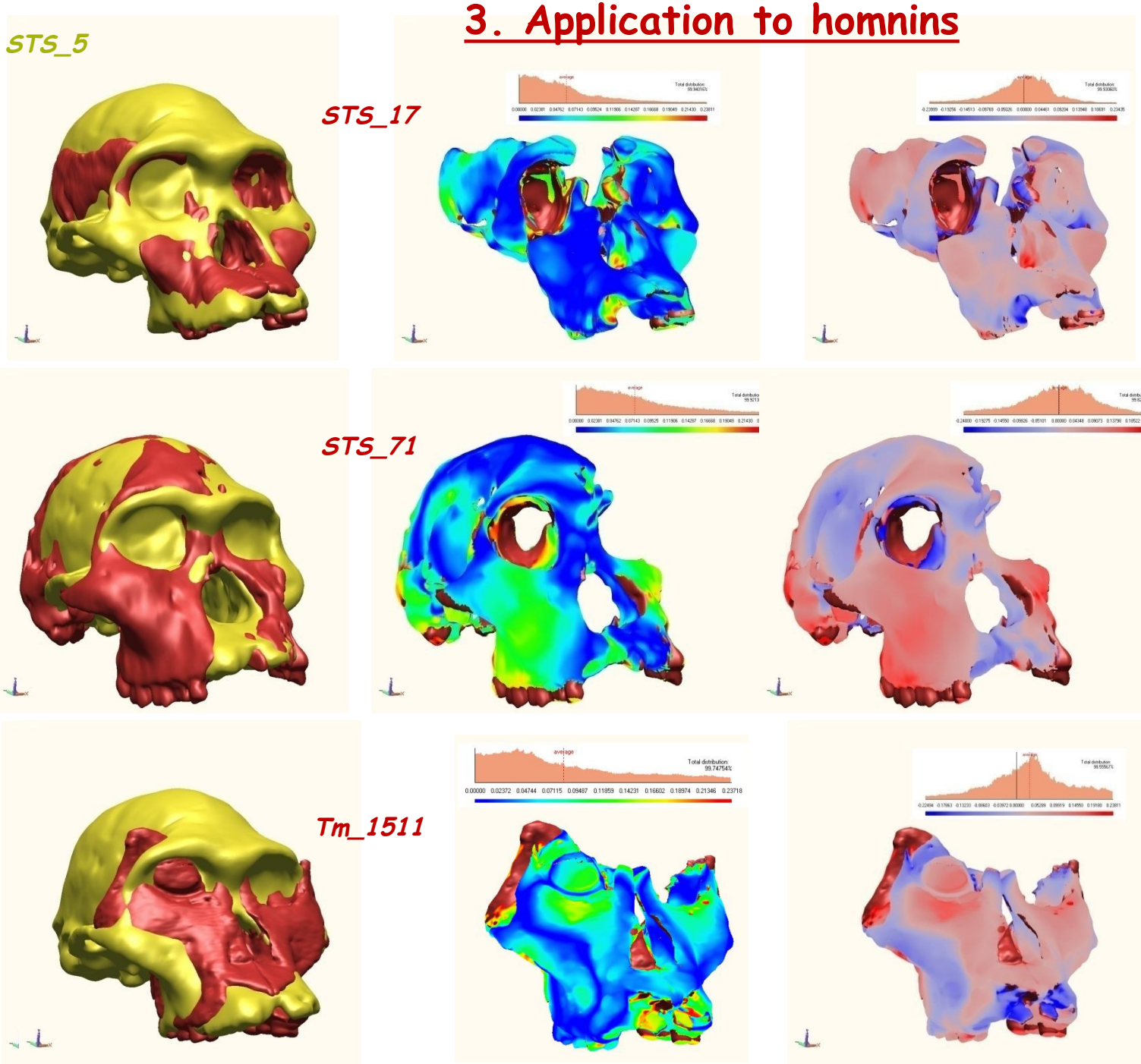
3. Application to homnins

STS_5

STS_17

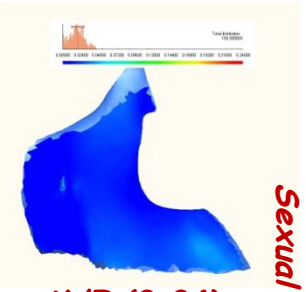
STS_71

Tm_1511

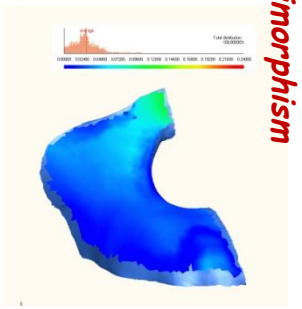


Reference maps

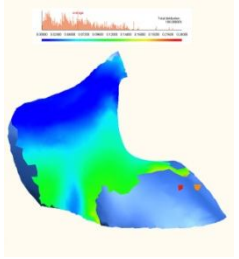
Pt – M/F (0.24)



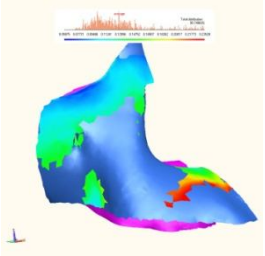
Pp – M/F (0.24)



F - Pt/Pp (0.24)

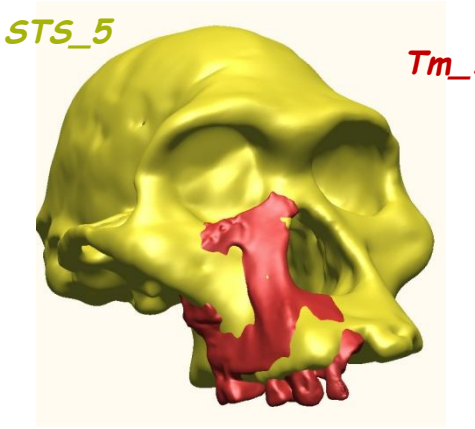


M - Pt/Pp (0.24)

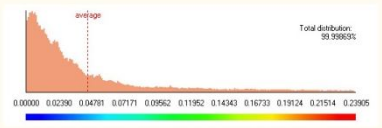


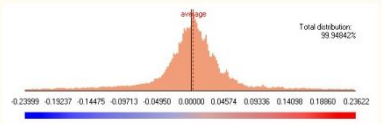
Sexual dimorphism

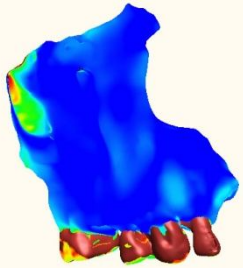
Inter-species variation

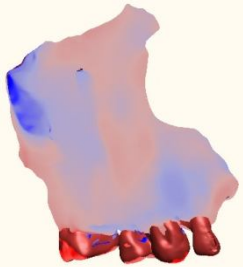


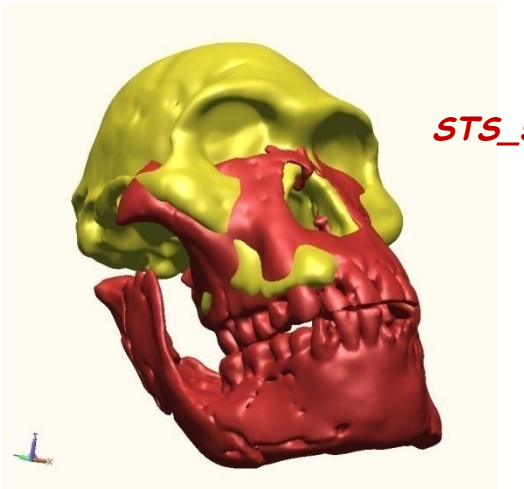
Tm_1512



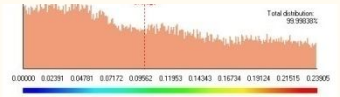


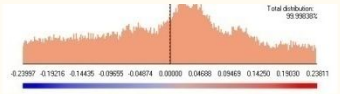


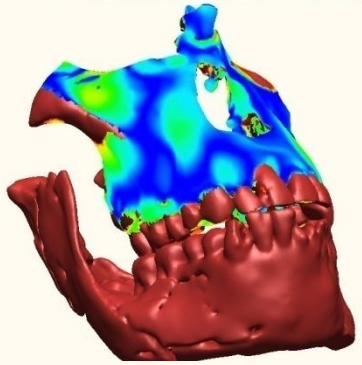


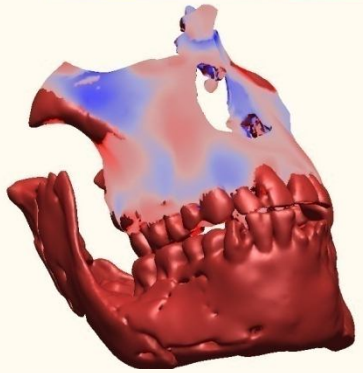


STS_52

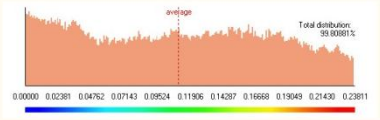


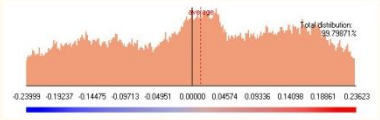


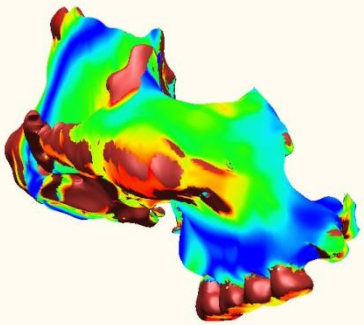


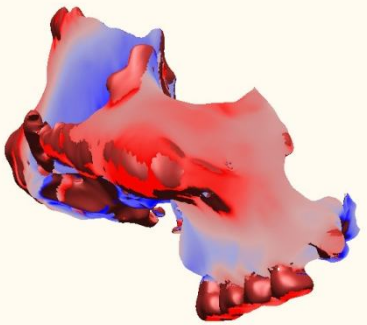


Tm_1517



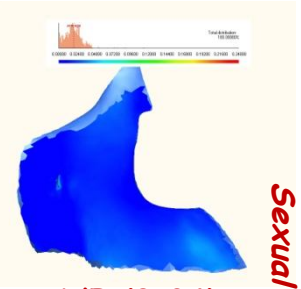






Reference maps

Pt – M/F (0.24)



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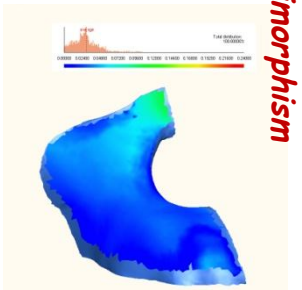
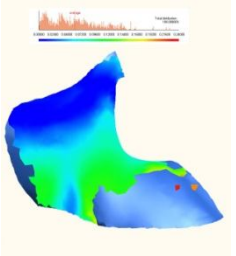
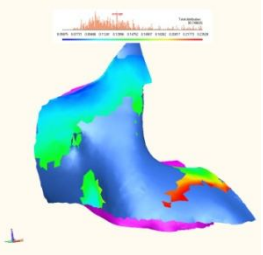


F - Pt/Pp (0.24)



M - Pt/Pp (0.24)



Sexual dimorphism

Inter-species variation

Future directions

Increase the reference sample size

Emphasize the local size/shape changes

Quantify the variability w.r.t. to the mean

Improve the automatic non-rigid registration algorithm

Automatic identification w.r.t. to the sexual dimorphism and inter-species variation

Multi-scale analysis (skull/Inf.-orb./pillars-clivus-IOconcavities-zygo)

Acknowledgements

Centre National de la Recherche Scientifique (PEPS-ODENT Project)

EU PF6 Marie Curie Actions grant MRTN-CT-2005-019564 'EVAN'

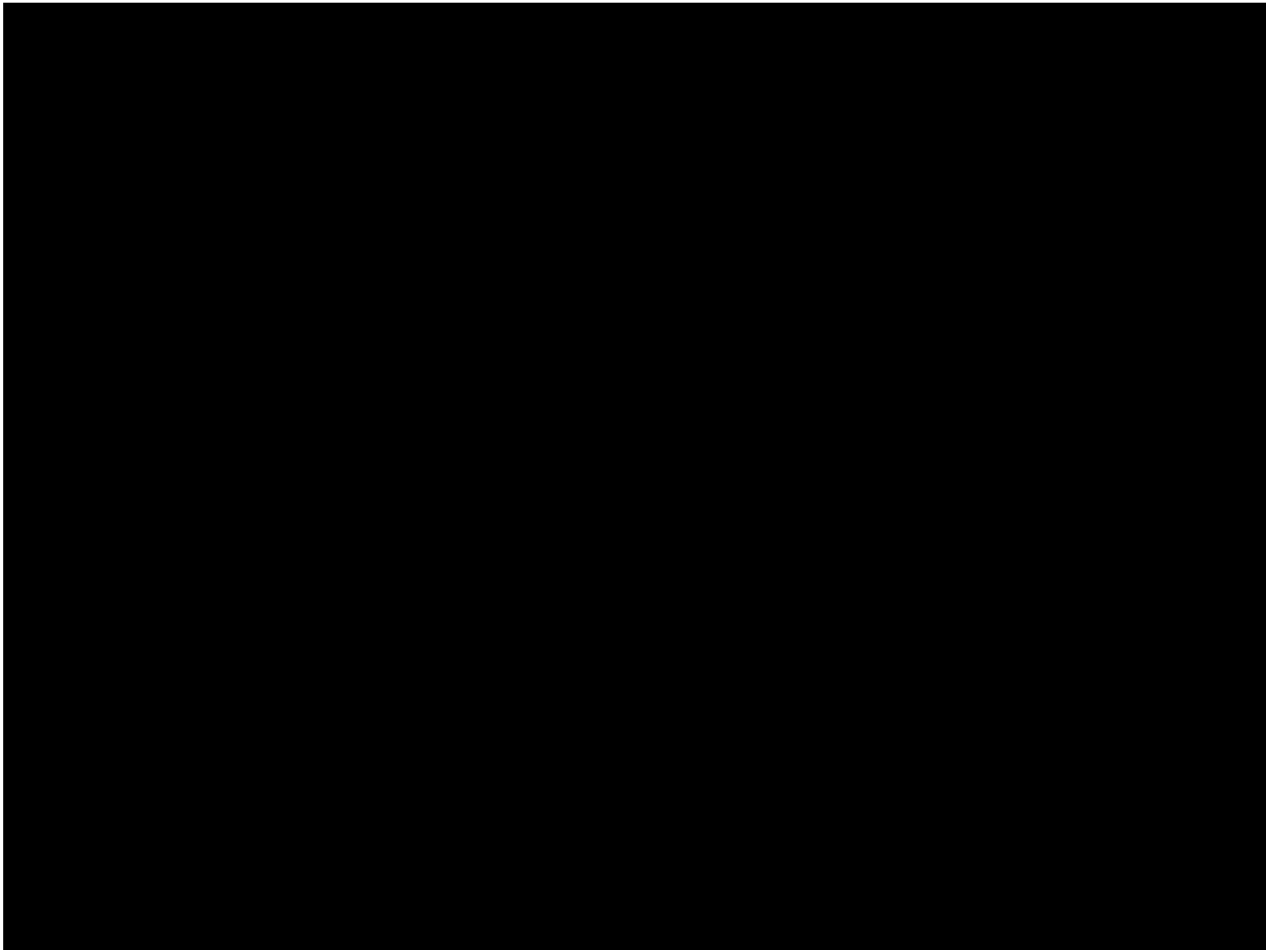
French Ministry of Foreign Affairs

Human Origins and Past Environments programme, Transvaal Museum, South Africa

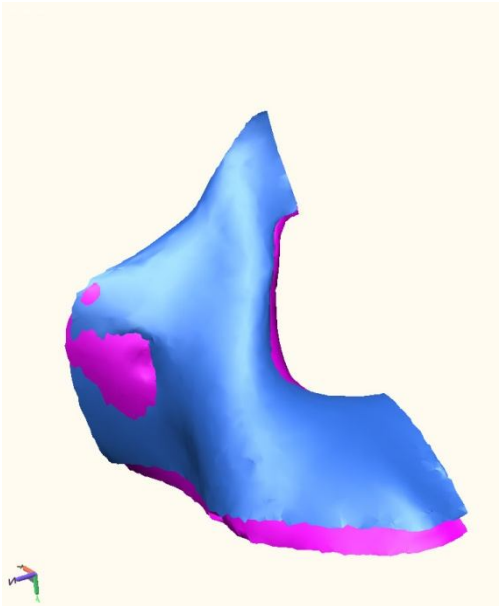
EVAN
setting landmarks in science

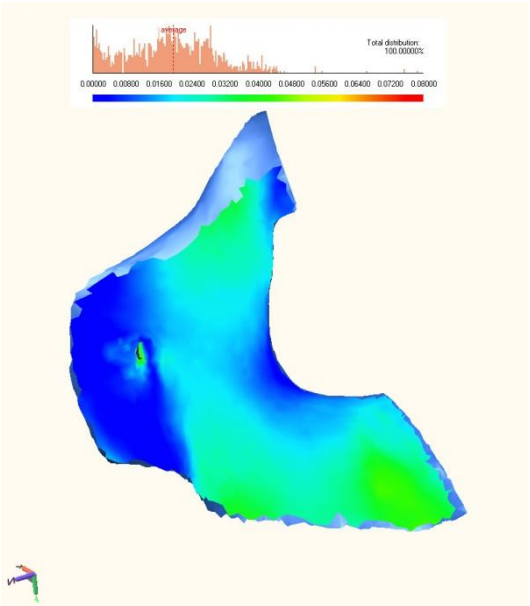
CNRS CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

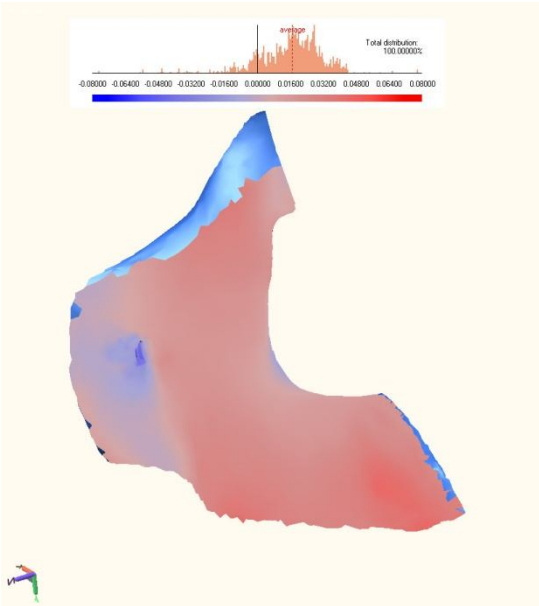
PEPS / ODENT



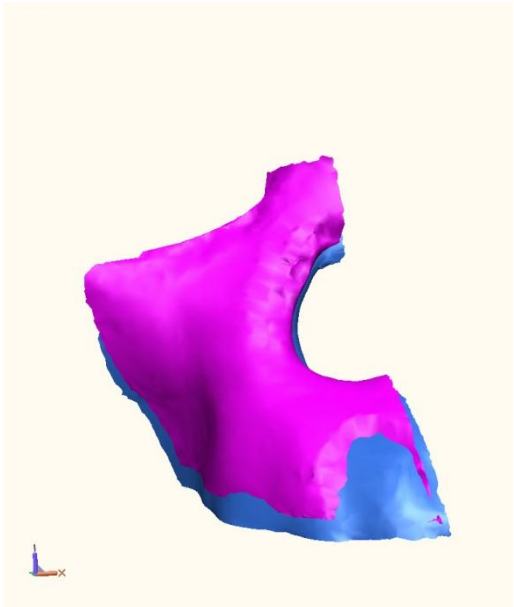
Pan troglodytes : Male mean surface / Female mean surface / whole skull

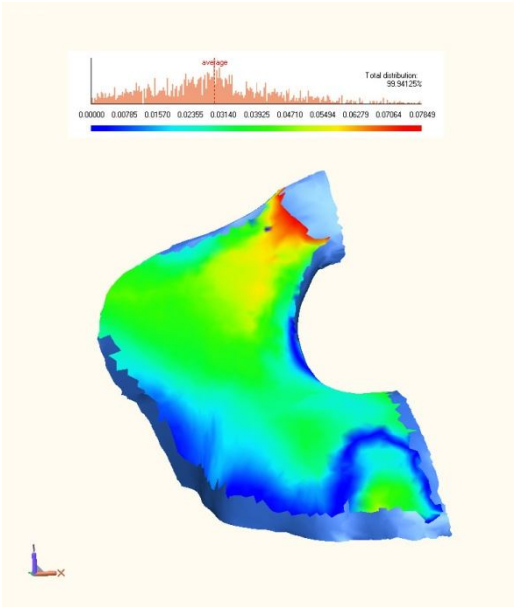


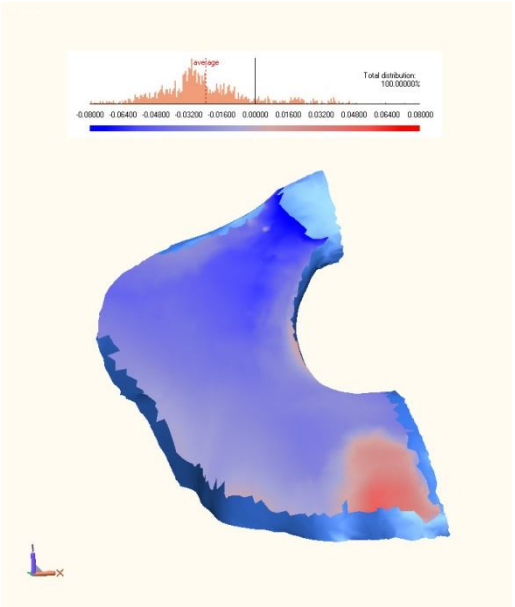




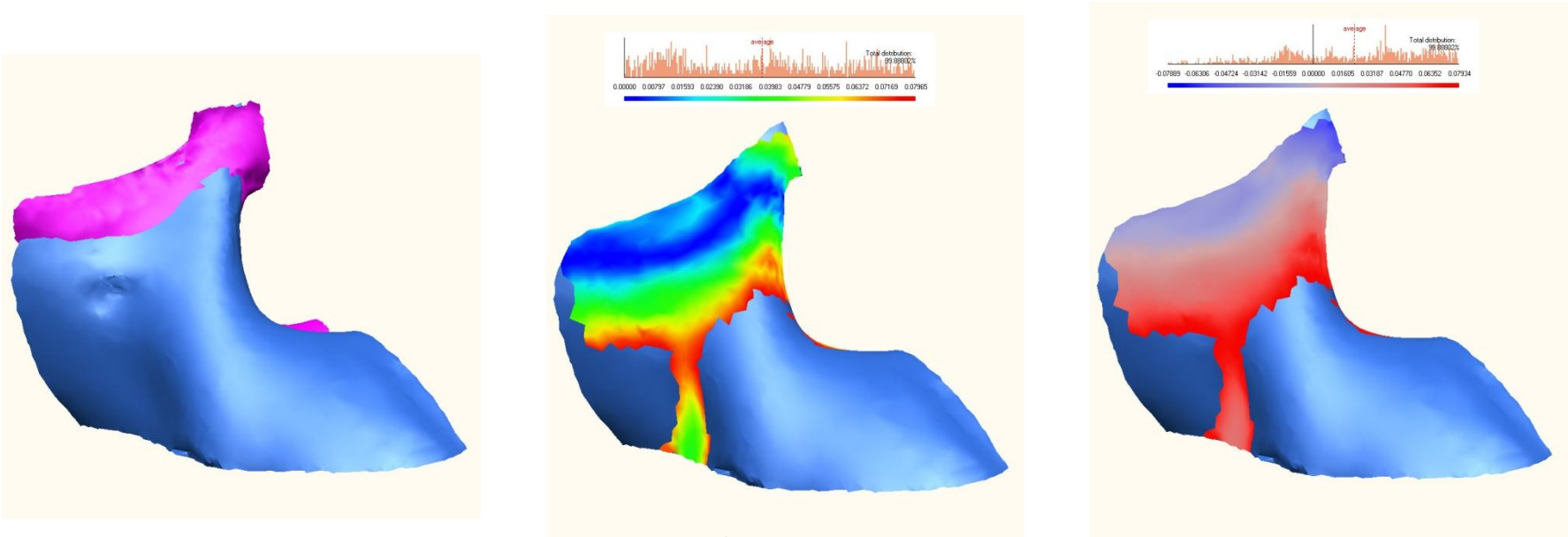
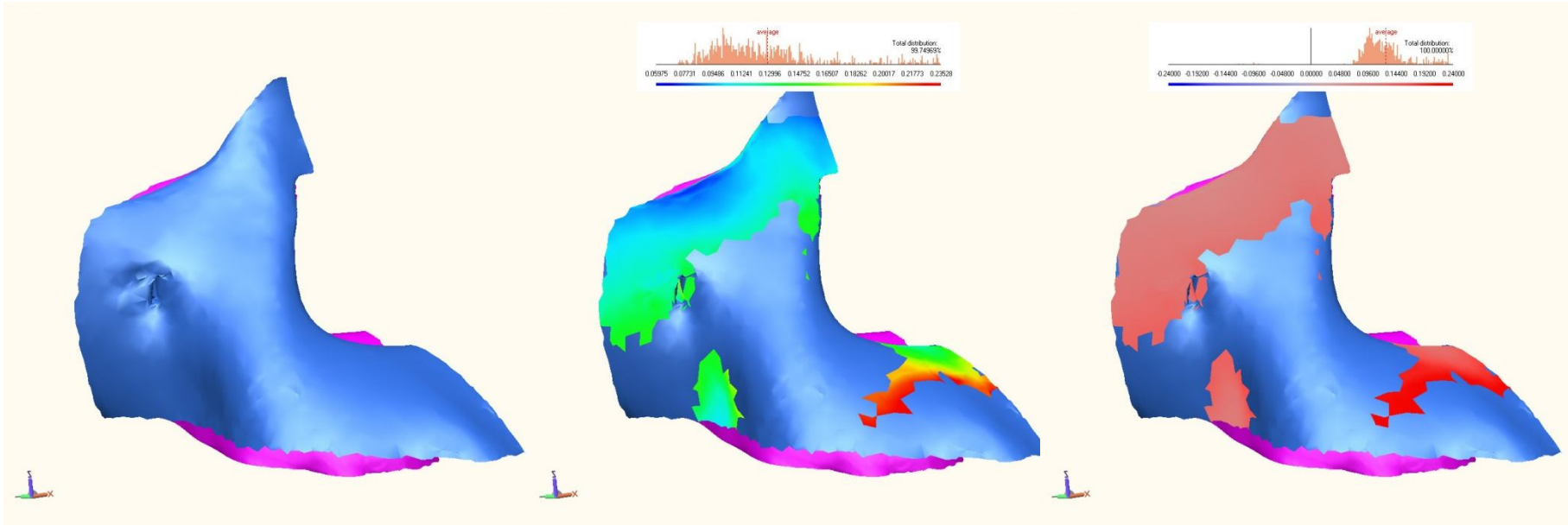
Pan paniscus : Male mean surface / Female mean surface / whole skull







Females : *P. troglodytes* mean surface / *P. paniscus* mean surface (scale : 0.08)



Males : *P. troglodytes* mean surface / *P. paniscus* mean surface (scale : 0.24)