Monte Carlo Simulations of Digital Diaphanoscopy in Spherical Geometry: a Pilot Study

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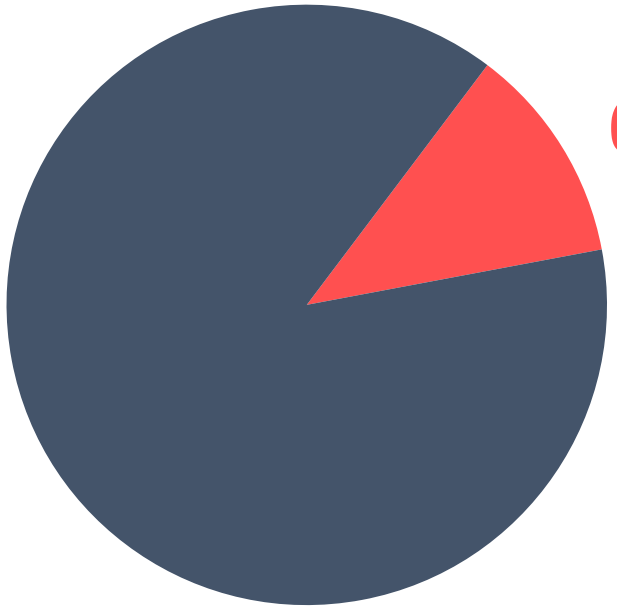
Motivation

20% OF PEOPLE IN THE WORLD

SUFFER FROM DISEASES OF THE PARANASAL SINUSES

>10 MILLION PEOPLE

IN RUSSIA

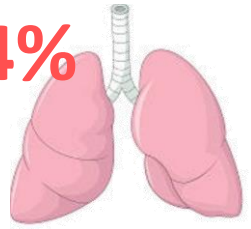


60 BILLION RUBLES

ANNUAL COSTS FOR THE TREATMENT OF SINUS DISEASES IN RUSSIA

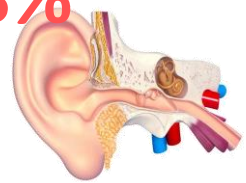
COMPLICATIONS

34%



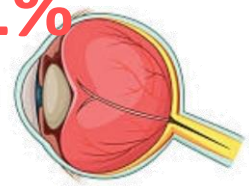
Laryngitis, Pharyngitis, Bronchitis

28%



Otitis

21%

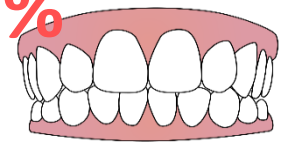


Periostitis of the eye socket, Phlegmon

8%

Meningitis

7%



Periodontitis, Periostitis

2%

Myocarditis, Sepsis

! MORTALITY FROM INTRACRANIAL COMPLICATIONS – **50%**

Motivation

- Digital diaphanoscopy has high potential for screening of ENT pathologies
- Optical diagnostics technique benefit from noninvasiveness, safety and convenience in clinical application
- Clinical use of digital diaphanoscopy requires proper choice of probing radiation power that fits safety requirements and provides valuable diagnostic information
- Diagnostic information provided by digital diaphanoscopy requires interpretation

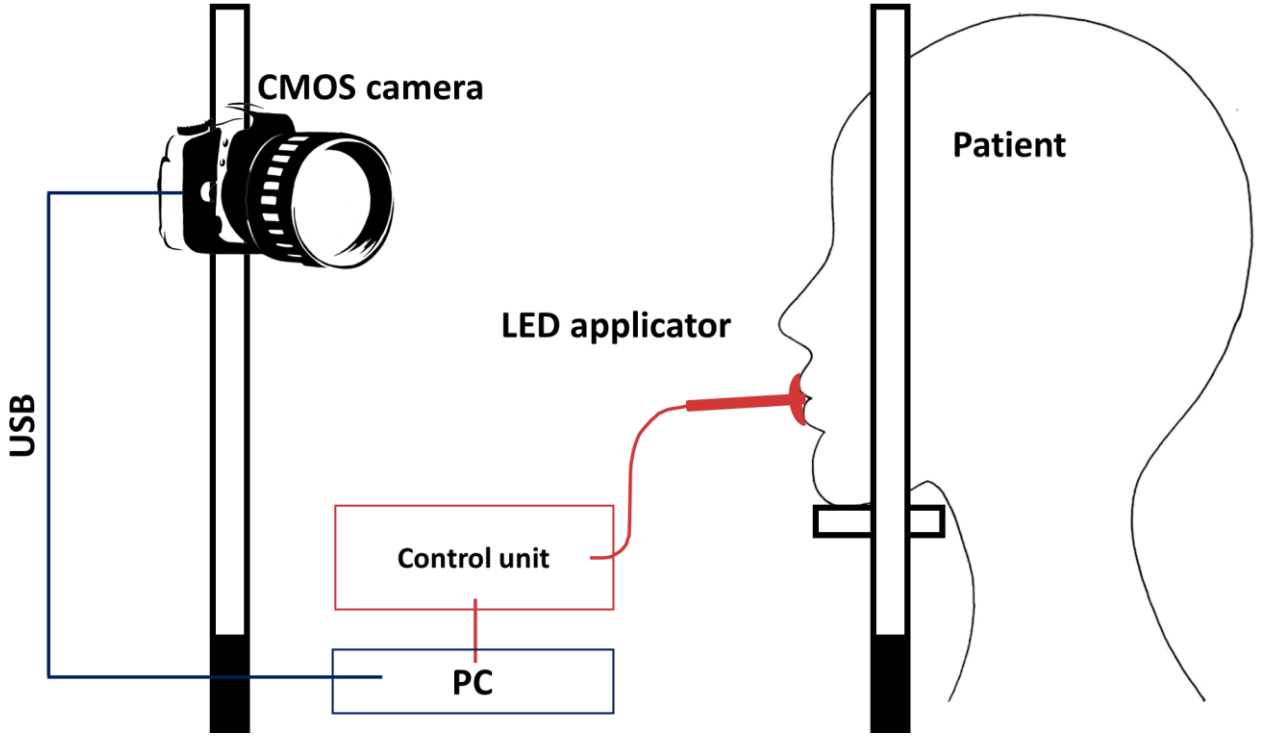
- Numerical simulations of signal formation in digital diaphanoscopy may provide a solution for these problems
- Monte Carlo technique provides the opportunity for solution of the problem in complex geometry

Digital Diaphanoscopy

Diaphanoscopy is a cutting-edge method of optical diagnosis of ENT organs disorders, primary aimed at diagnostics of nasal sinuses.

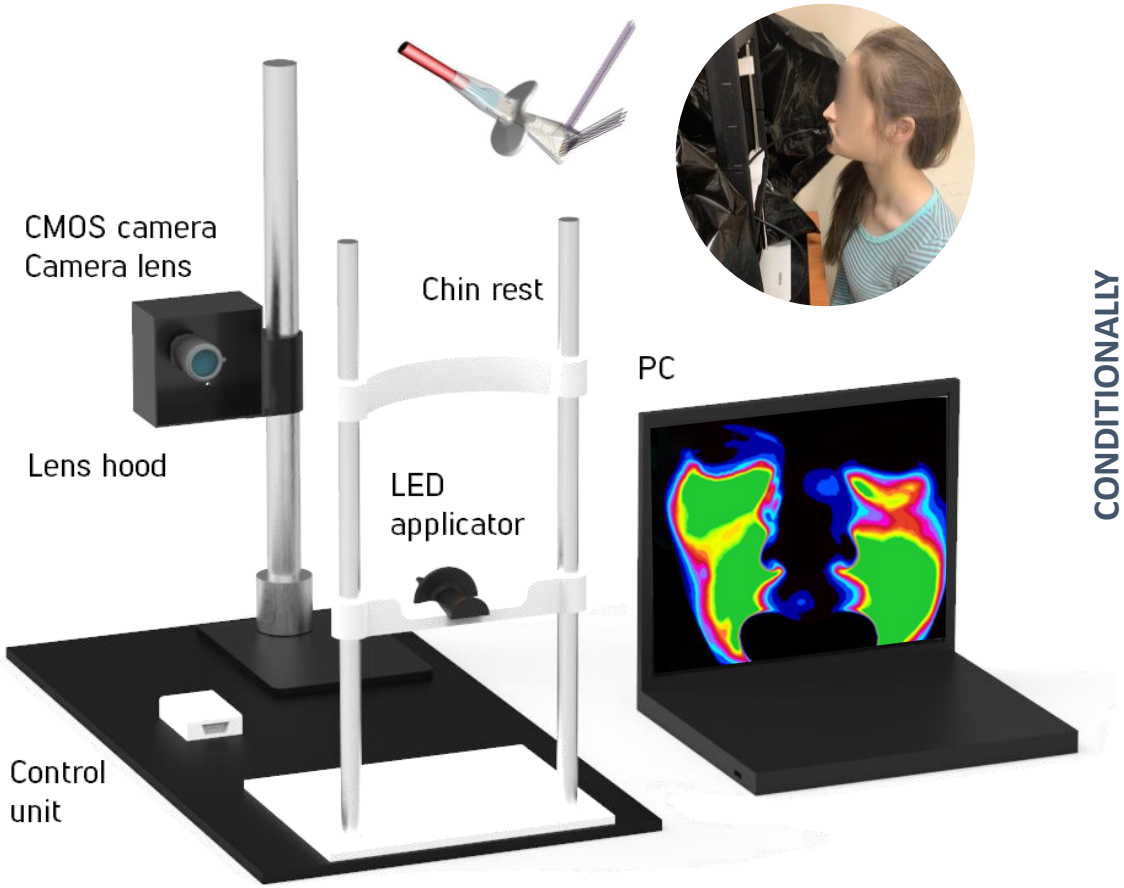
The diagnostics procedure involves inserting a light source into the patient's oral cavity and measuring the radiation transmitted through the tissues using a CMOS camera located in front of the patient’s head.

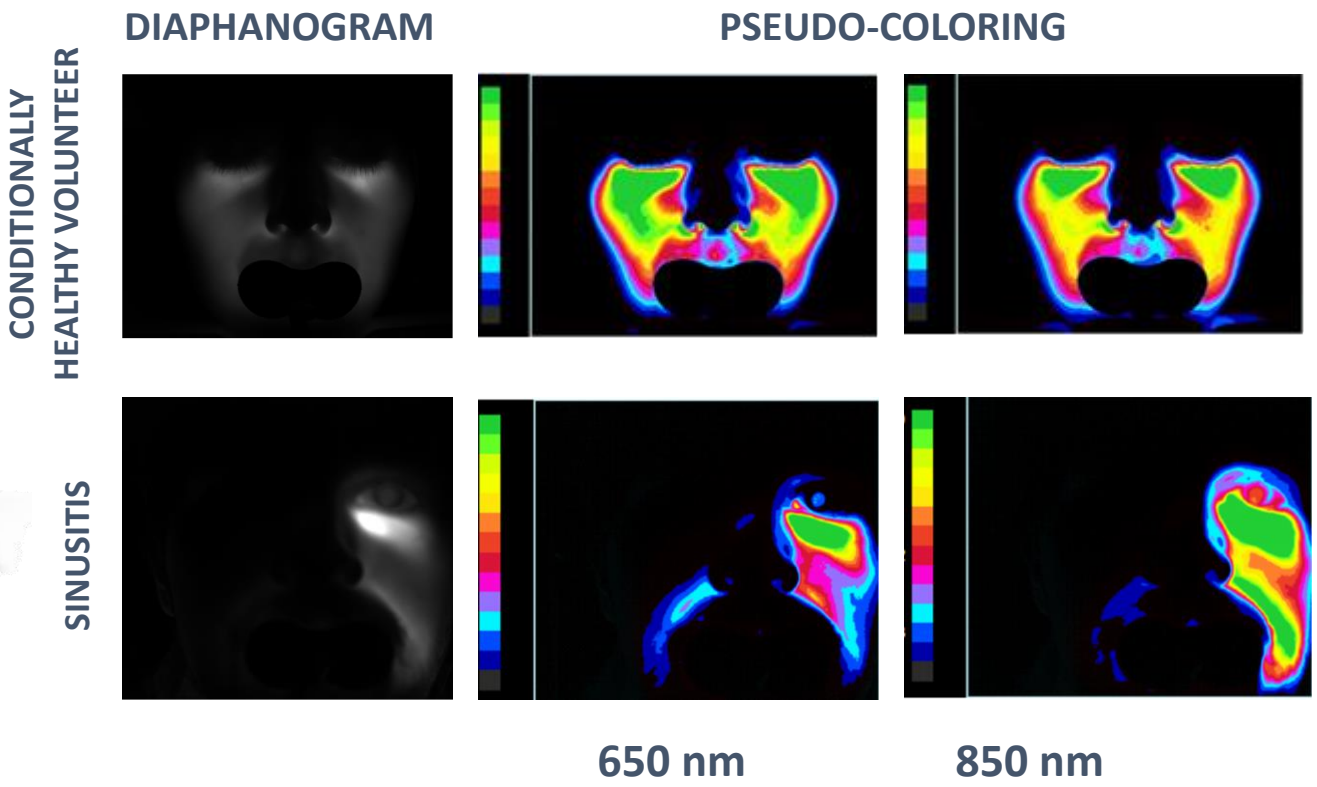
Spectral dependence of biotissue optical properties provide opportunities for dual-wavelength probing implementation.



- Application in telemedicine
- Safe and painless
- Portability and mobility
- Cost-effective screening method

Digital Diaphanoscopy device



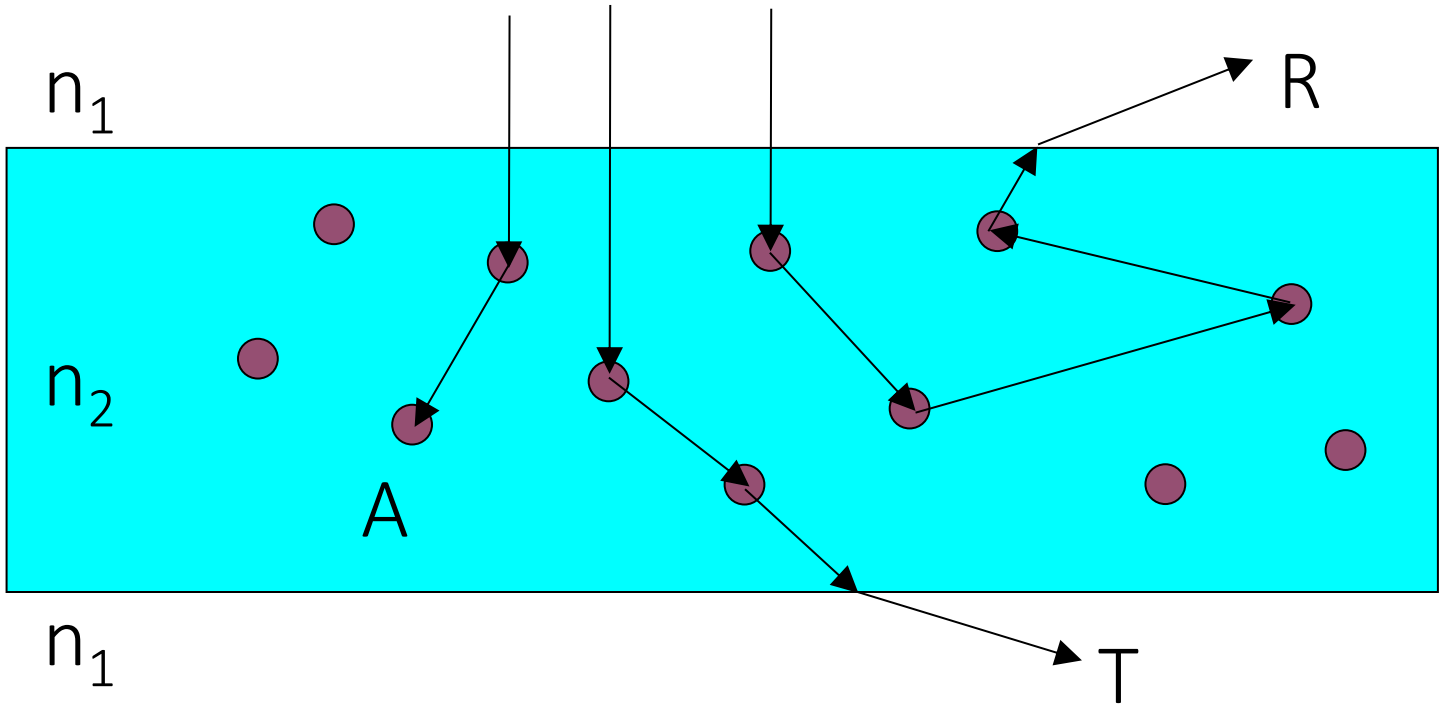


Wavelengths of LED-applicator:

- ✓ 650 nm
- ✓ 850 nm

Camera: UI-3240CP Rev.2

Principles of Monte Carlo simulations



Input parameters

μ_s : scattering coefficient

μ_a : absorption coefficient

$p(\boldsymbol{s},\boldsymbol{s'})$: scattering phase function

g: anisotropy factor

n: refractive index

R: reflected photon

A: absorbed photon

T: transmitted photon

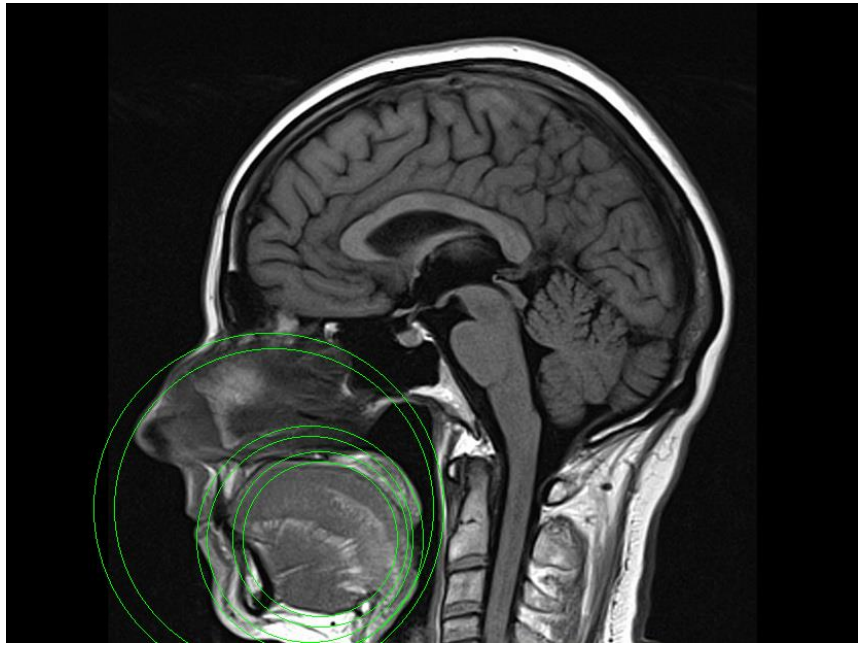
Implementation of the model for spherical geometry mimicking human head anatomy

Spherical geometry mimicking human ENT organs anatomy is employed for Monte Carlo simulations.

Optical properties of nasal sinuses content in norm and pathology for different probing wavelength

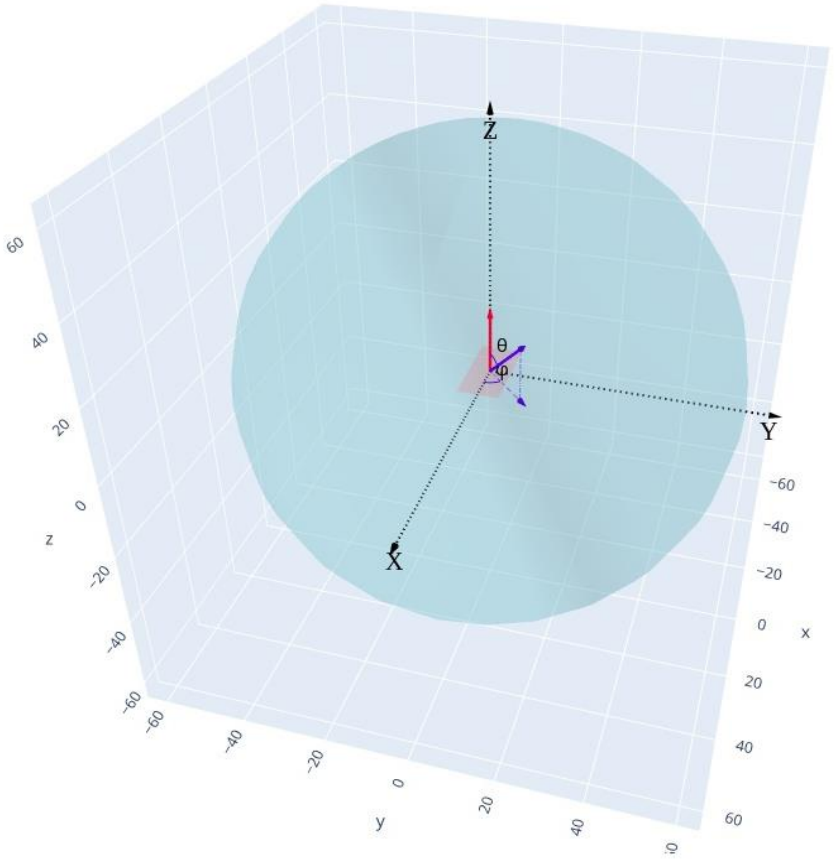
$\lambda = 650$ nm	μ_a, mm^{-1}	μ_s', mm^{-1}
Air	0.0	0.0
Excaudate	0.101	0.396
Tumor	0.039	2.17

$\lambda = 850$ nm	μ_a, mm^{-1}	μ_s', mm^{-1}
Air	0.0	0.0
Excaudate	0.064	0.306
Tumor	0.052	2.67

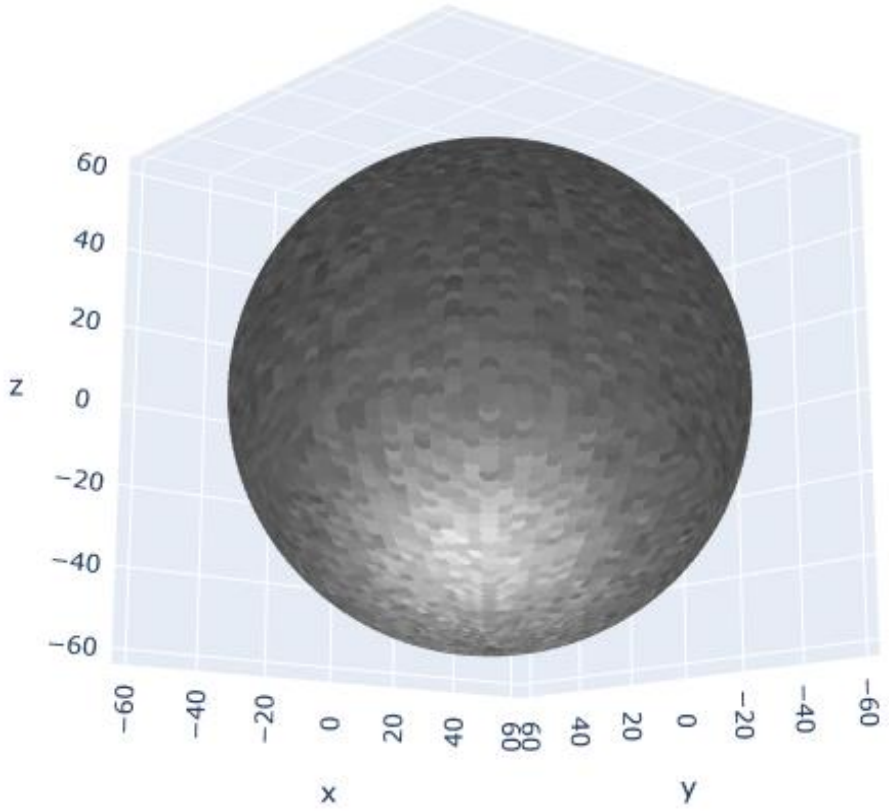


Data visualization

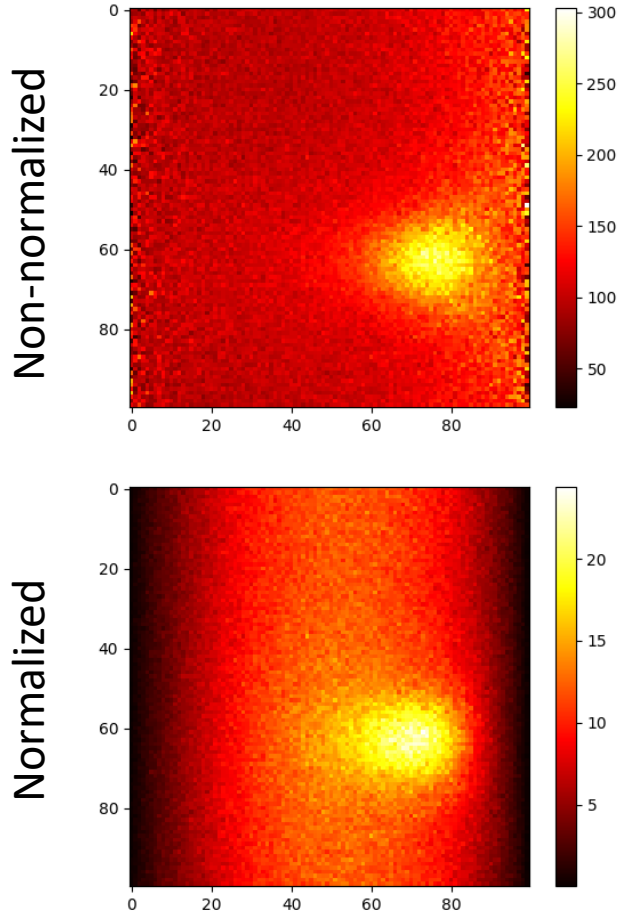
Probing geometry



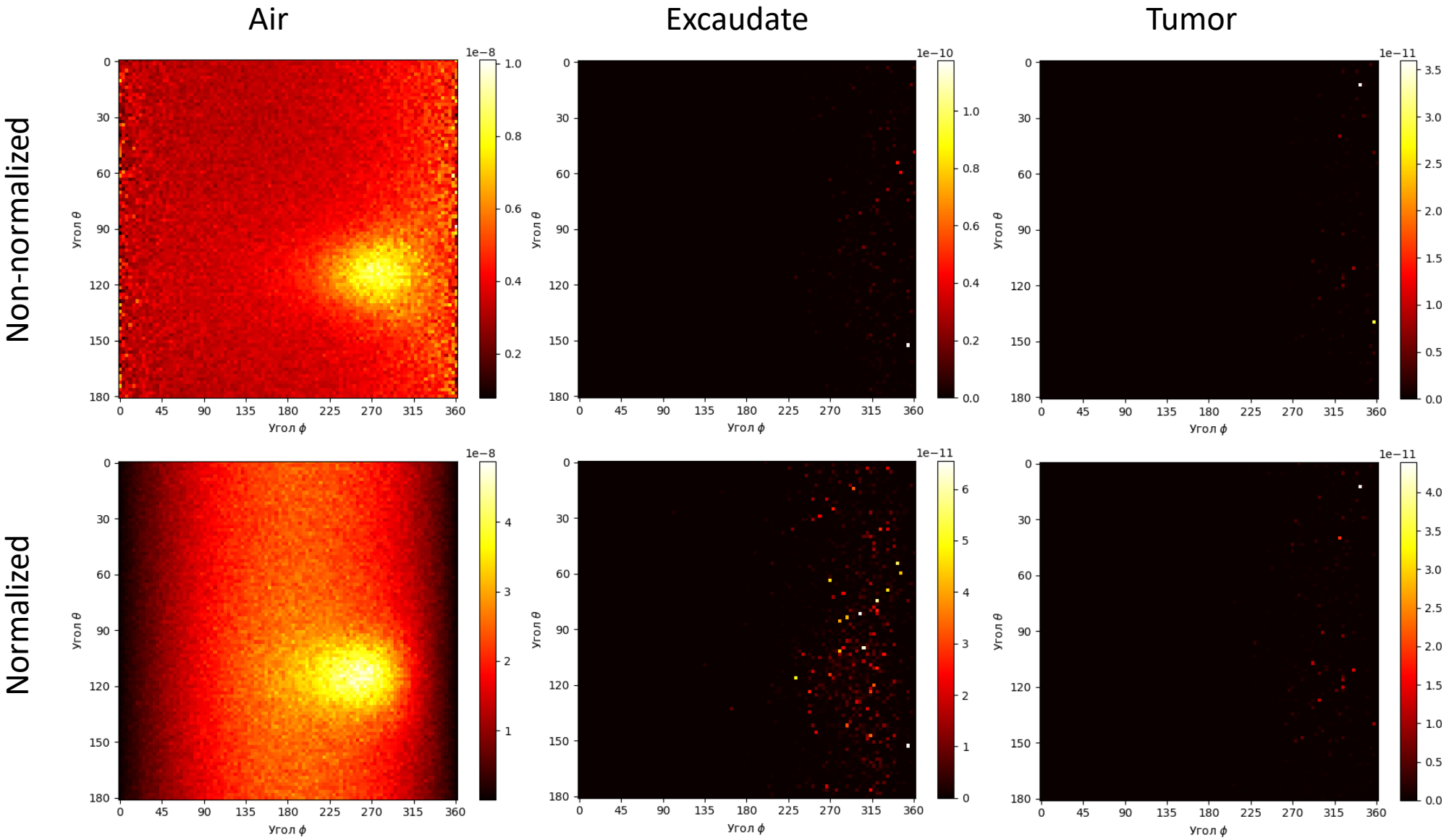
Spherical visualization of radiation distribution



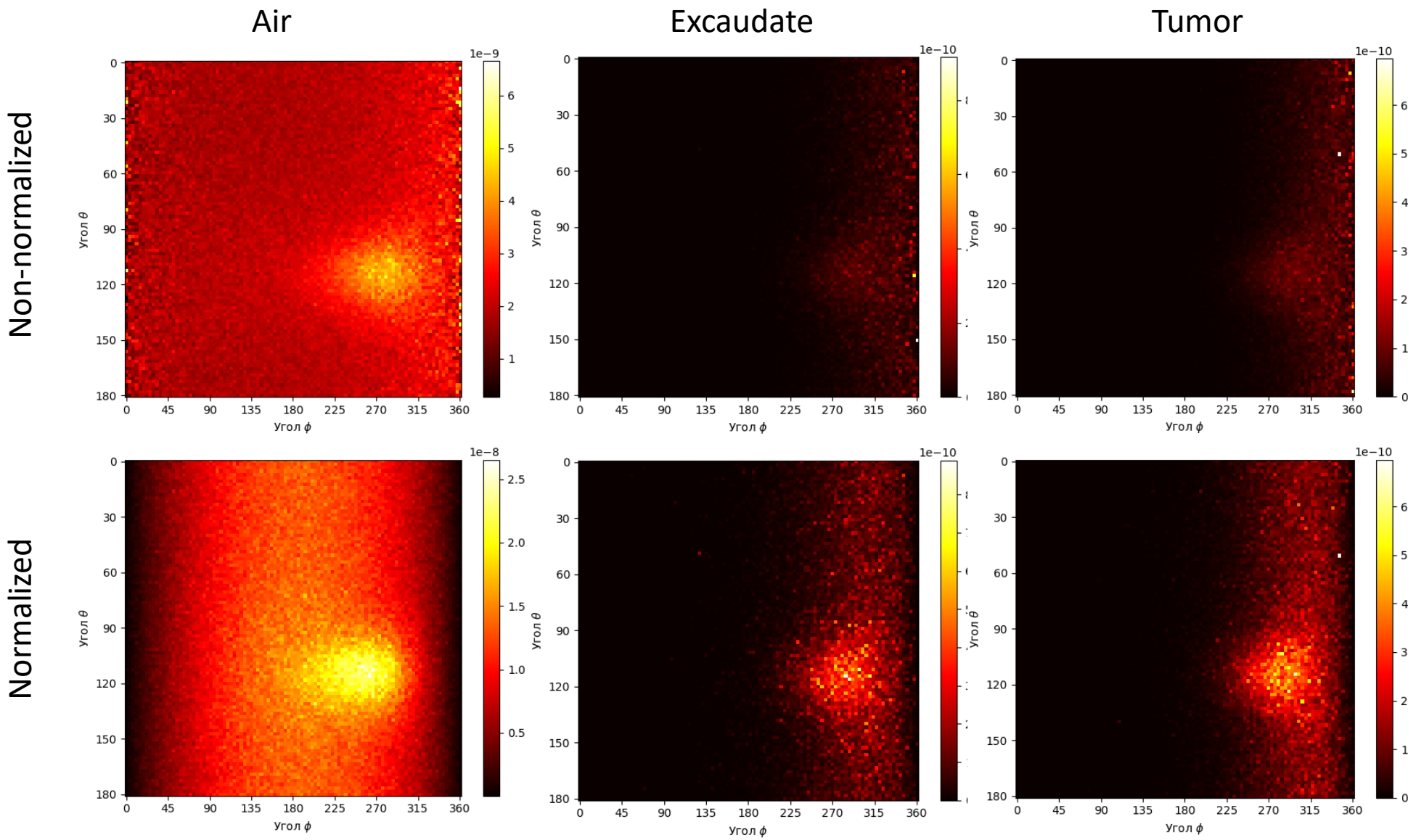
Radiation map
in spherical coordinates



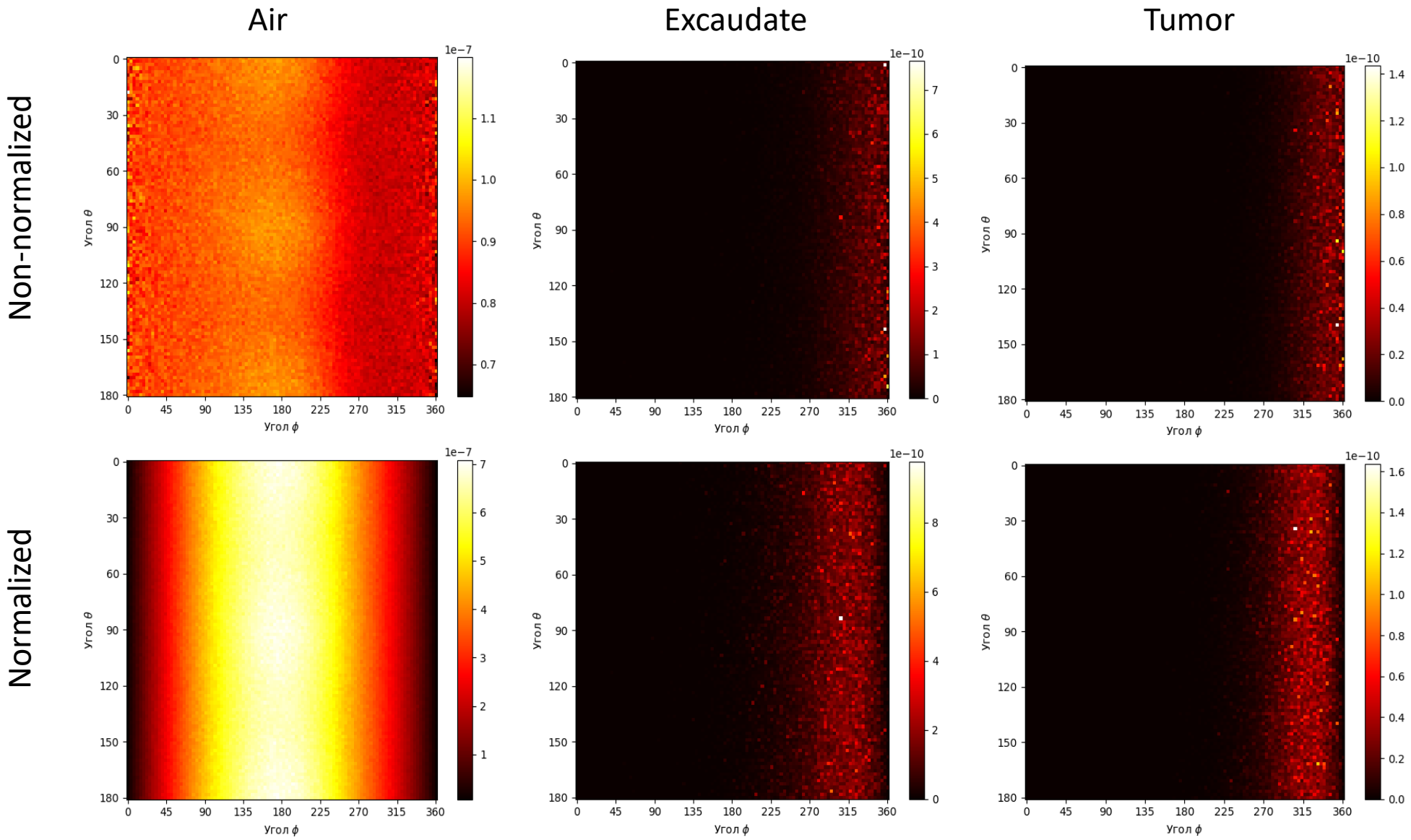
Probing with point source (λ = 650 nm)



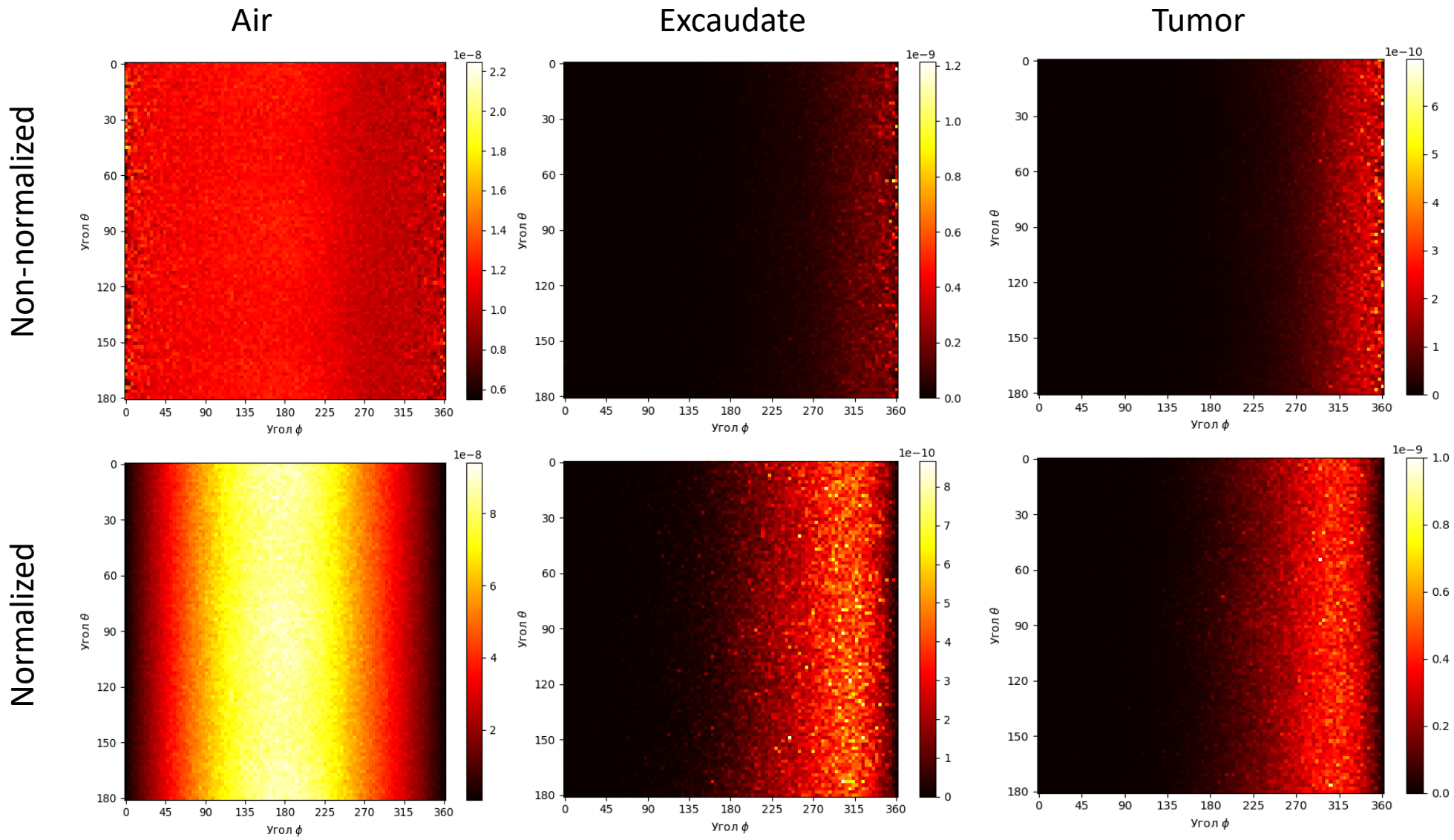
Probing with point source (λ = 850 nm)



Probing with flat source (λ = 650 nm)



Probing with flat source (λ = 850 nm)



Conclusions

- The Monte Carlo method of modeling the propagation of radiation in a scattering medium is implemented in spherical geometry mimicking human ENT organs anatomy.
- Angular distribution of scattered radiation is simulated to mimic signals of digital diaphanoscopy.
- A simulation of signal formation in digital diaphanoscopy was carried out for two probing wavelengths used in real systems.
- It has been shown that in the presence of an exudate or tumor in the sinus, the diaphanoscopy signal is significantly reduced.
- Numerical modeling made it possible to quantify the typical signal levels for norm and pathology.

Acknowledgements

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Thank you for your attention!

Questions?