We propose a biophysical cortical column model, at a some mesoscopic scale, in order to better understand and start to interpret biological sources of voltage-sensitive dye imaging signal. The mesoscopic scale, corresponding to a micro-column, is about 50 µm. Simulations are done thanks to the NEURON and NEUROCONSTRUCT software. This model suggests that the OI signal is the result of an average from multiple components whose proportion changes with levels of activity and shows surprisingly that inhibitory cells, spiking activity and deep layers may well participate more to the signal than initially thought.

Model behaviour
- Single Neurons: Firing rate vs. current intensity (f-I curves)
  - Action potential response to depolarizing current injection in the two main populations of respectively excitatory neurons and inhibitory neurons.
  - KS and PS cells are known to be relatively resistant to the influence of excitatory and inhibitory cells in the neocortex.

Network: Contrast response function (CRF)
- The CRF of excitatory and inhibitory population of sources predicted by the model.
- Each point is the average of the mean firing rate for 13 repetitions at a given contrast.

VSD signal computation
- For a given layer L, the OI signal computation is given by:
  \[ \text{OI} = \sum_{L} \lambda \cdot V(0.5) \cdot S_i \]
  where
  - \( N \) is the number of compartments in layer L
  - \( S_i \) is the surface of the \( i \)th compartment
  - \( V(0.5) \) is the membrane potential taken in the middle of the \( i \)th compartment
  - \( \lambda \) represents the fluorescence gradient of the dye in layer L

VSD signal contributions
- Normalized contributions of the different layers compared to the total signal

Conclusion
- This model confirms and quantifies the fact that the VSD signal mainly reflects dendritic activity of excitatory populations of superficial layers.
- However, the model also shows that inhibitory cells, spiking activity and deep layers are non-negligible and should be taken into account in the computation of the optical signal.