Corneal Topography

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Topography basics

- Using a Placido ring based topographer (eg. Medmont E300), what is measured?
  - The spacing of the reflected rings
  - Corneal slope (i.e. first derivative) is derived easily

- What can be calculated from the raw data?
  - Tangential/axial Radius of Curvature (mm)
  - Tangential/axial power (D)
  - Corneal height (µm)
  - Elevation (µm)

Reference points

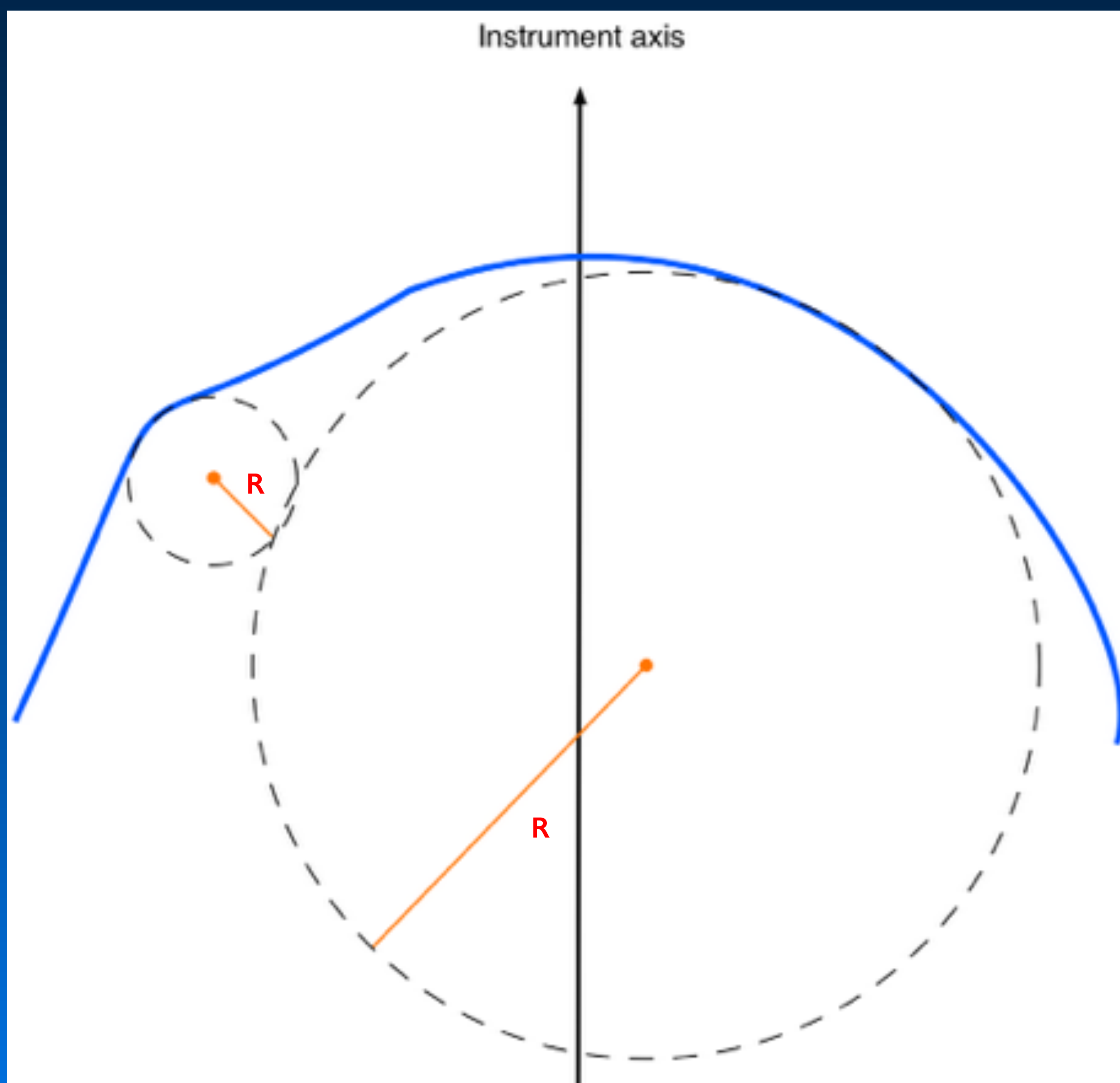
Three main reference points:

1. Geometric centre of cornea
2. Patient's line of sight
3. Instrument axis

Note the line of sight and geometric centre may not coincide. You should ask the patient to shift their line of sight away from the instrument axis, so that geometric centre of the cornea corresponds with the instrument axis

Tangential ROC

- Radius of the circular arc that best approximates the curve at that point



$$R = \left| \frac{(1 + y'^2)^{3/2}}{y''} \right|, \qquad \text{where} \quad y' = \frac{dy}{dx}, \quad y'' = \frac{d^2y}{dx^2},$$

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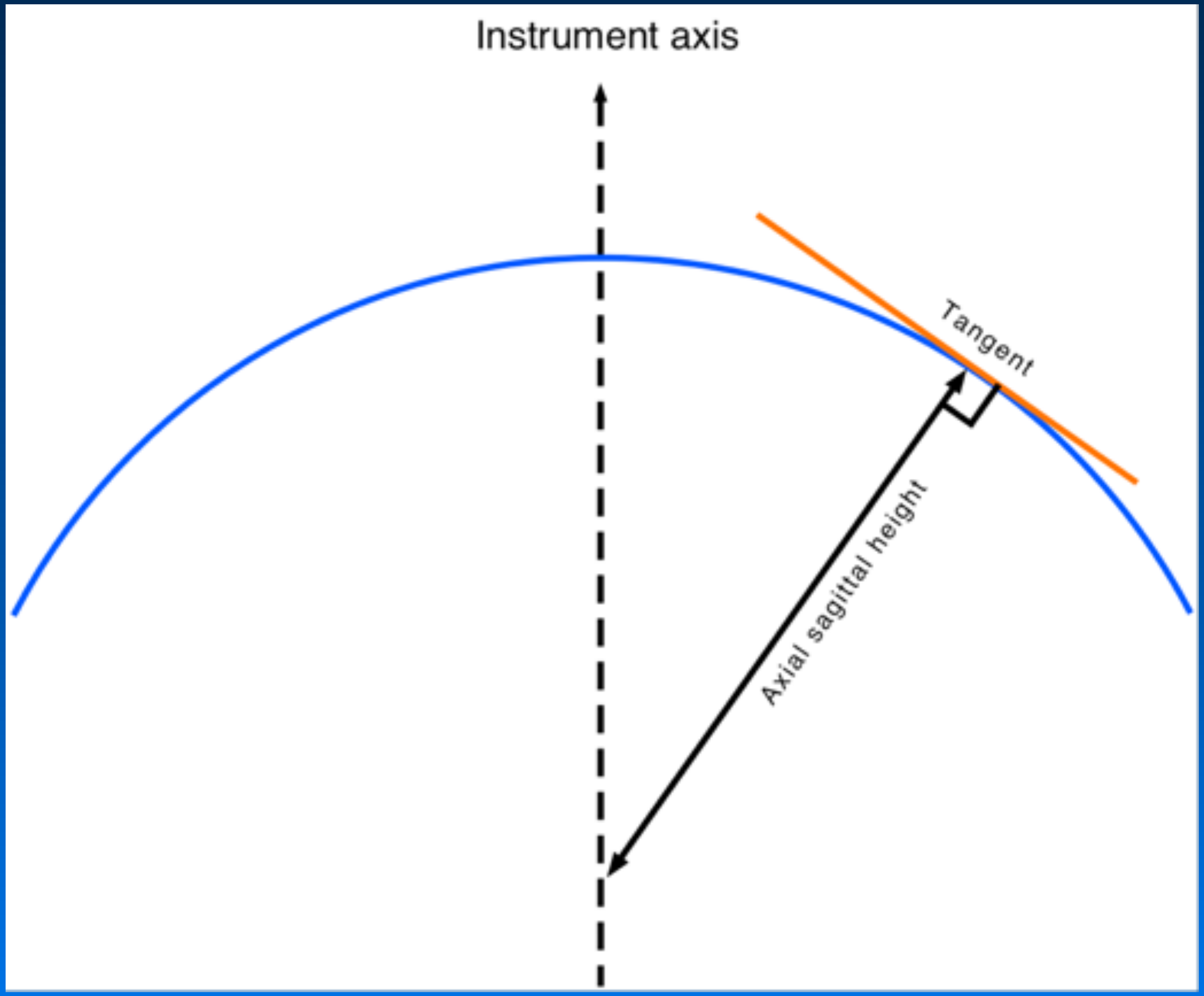
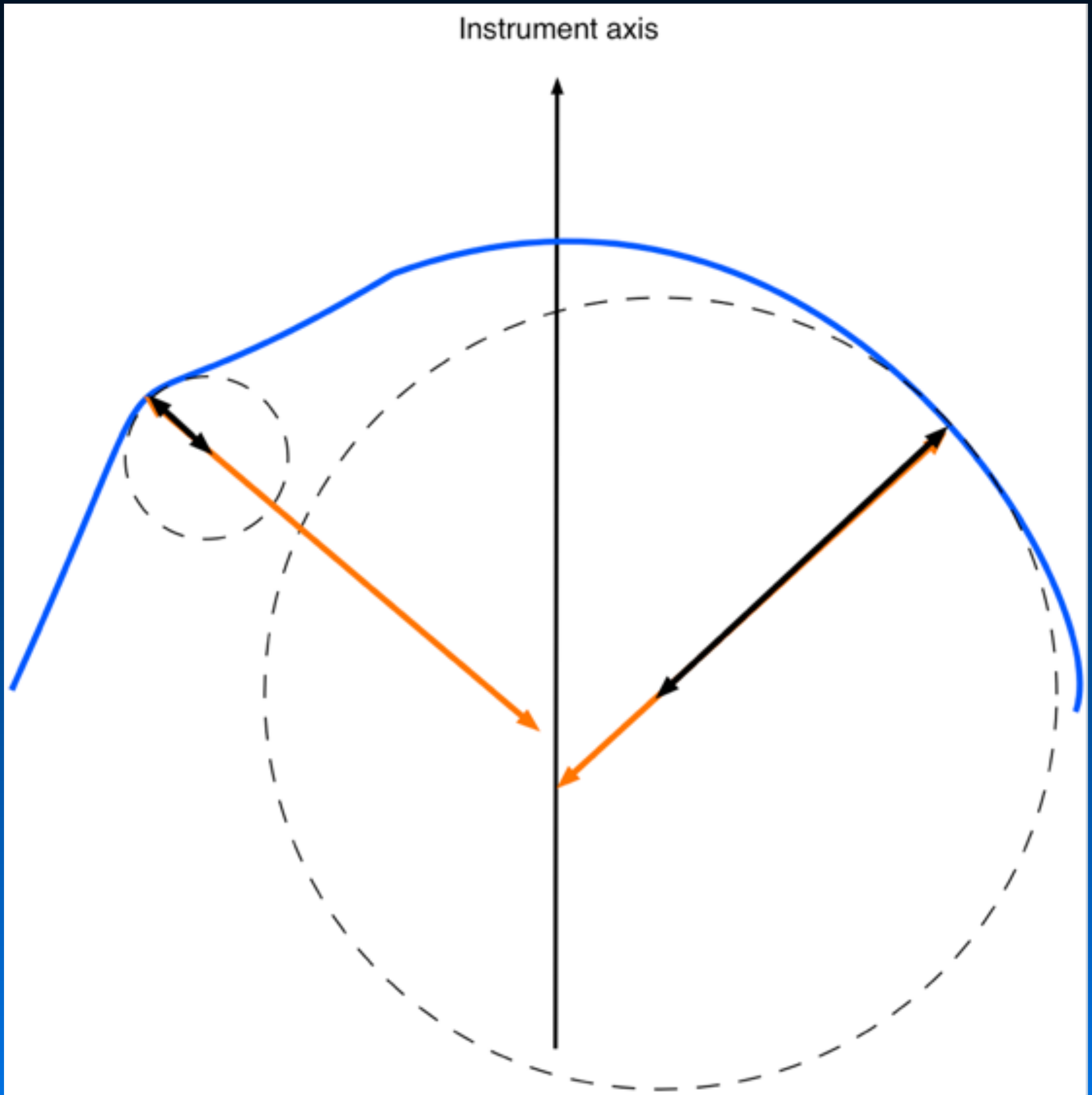
Axial ROC

- Also known as *axial sagittal height*
- Geometrically, just the distance from a point to the instrument axis, along the surface normal



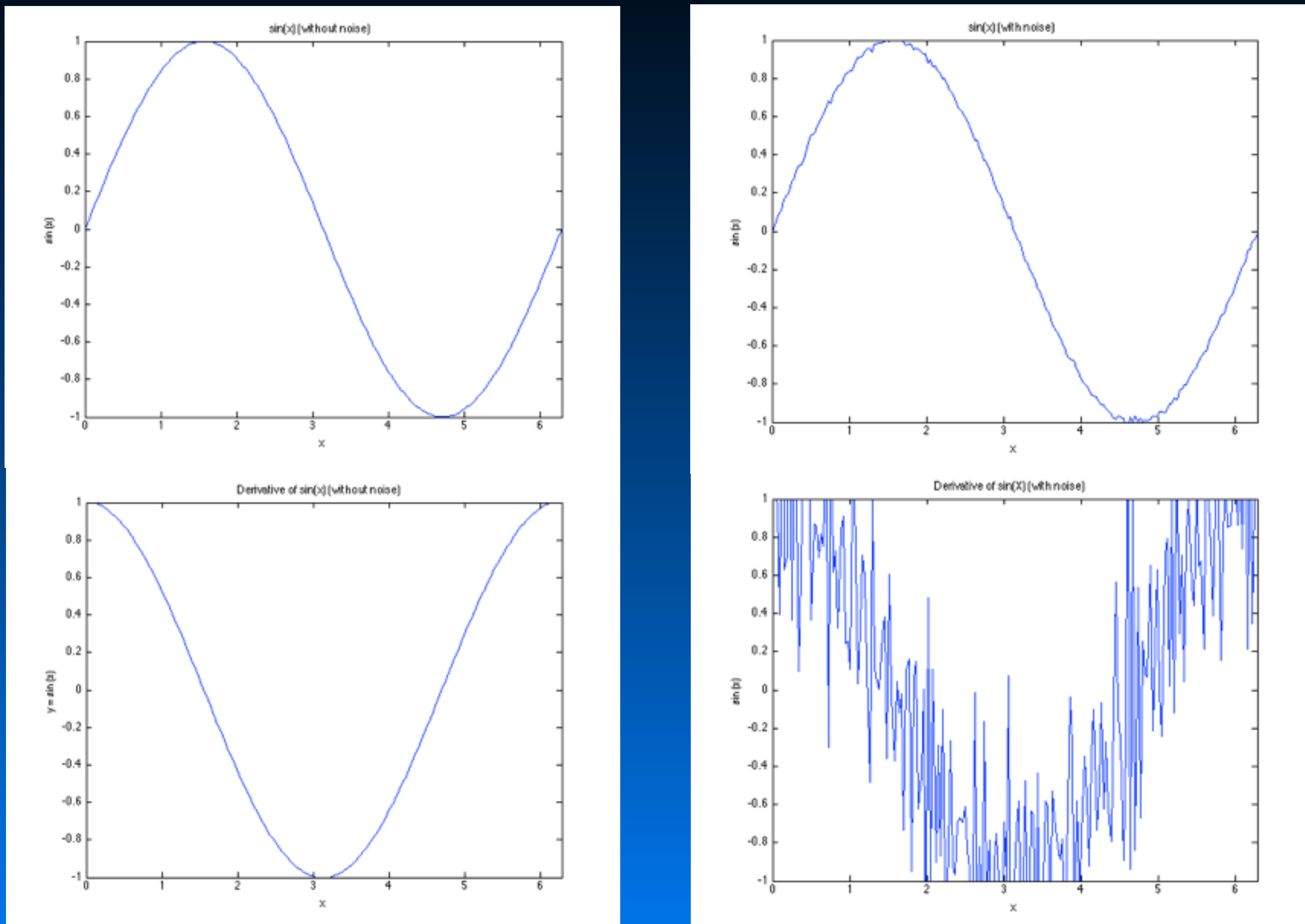
Comparison



Small scale variation

- Localized corneal variations are more visible in tangential than axial maps
- We can see why (mathematically) from a simple example

Derivatives amplify noise



Tangential vs axial

- Tangential:

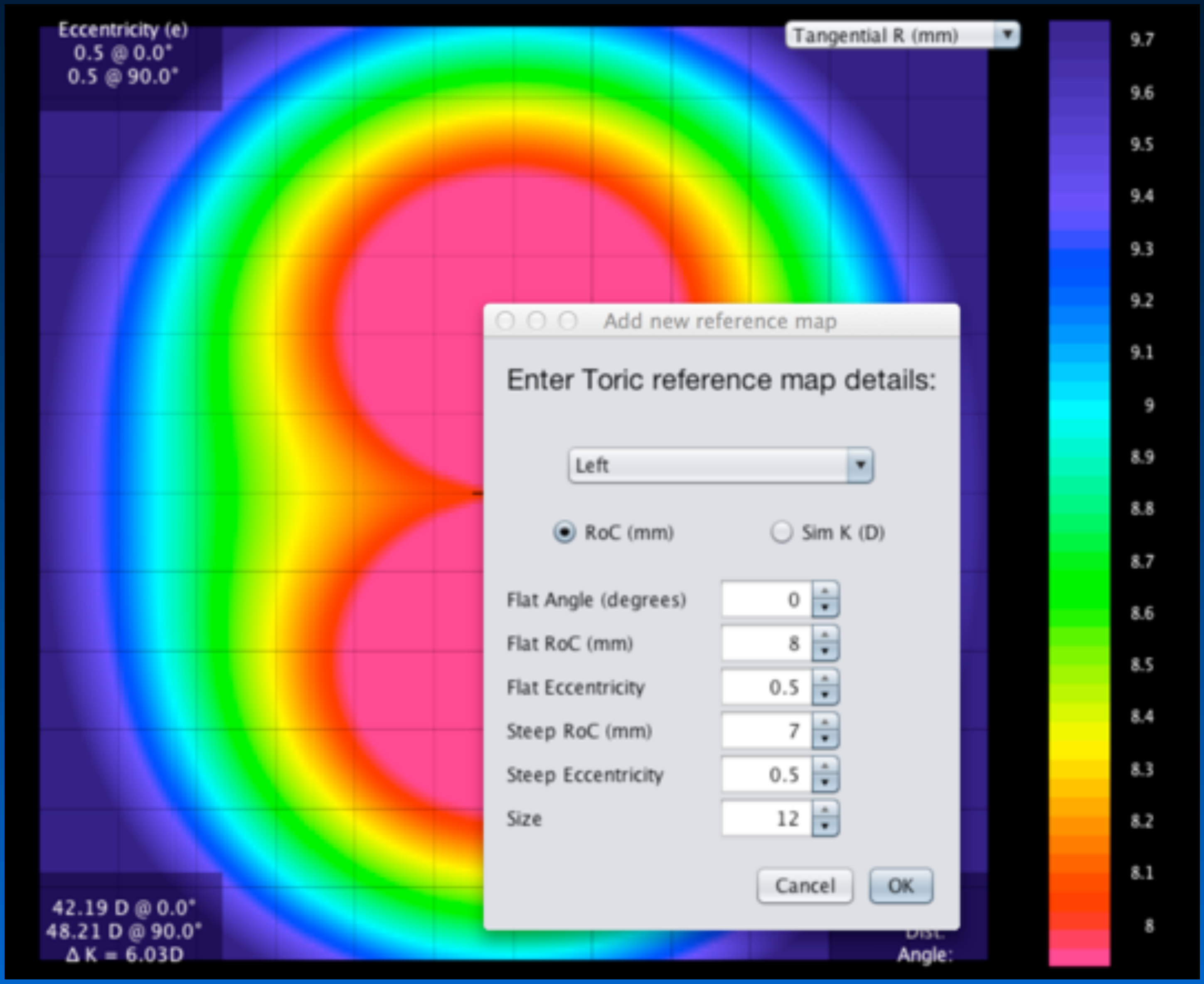
$$R = \left| \frac{(1 + y'^2)^{3/2}}{y''} \right|, \qquad \text{where} \quad y' = \frac{dy}{dx}, \quad y'' = \frac{d^2y}{dx^2},$$

- Axial:

  Simple geometric formula involving y'

Side note: reference maps

- EyeSpace includes the ability to create reference maps
- These allow you to enter the apical RoC and eccentricity, and then treat this artificial map like a normal corneal topography to design lenses etc.



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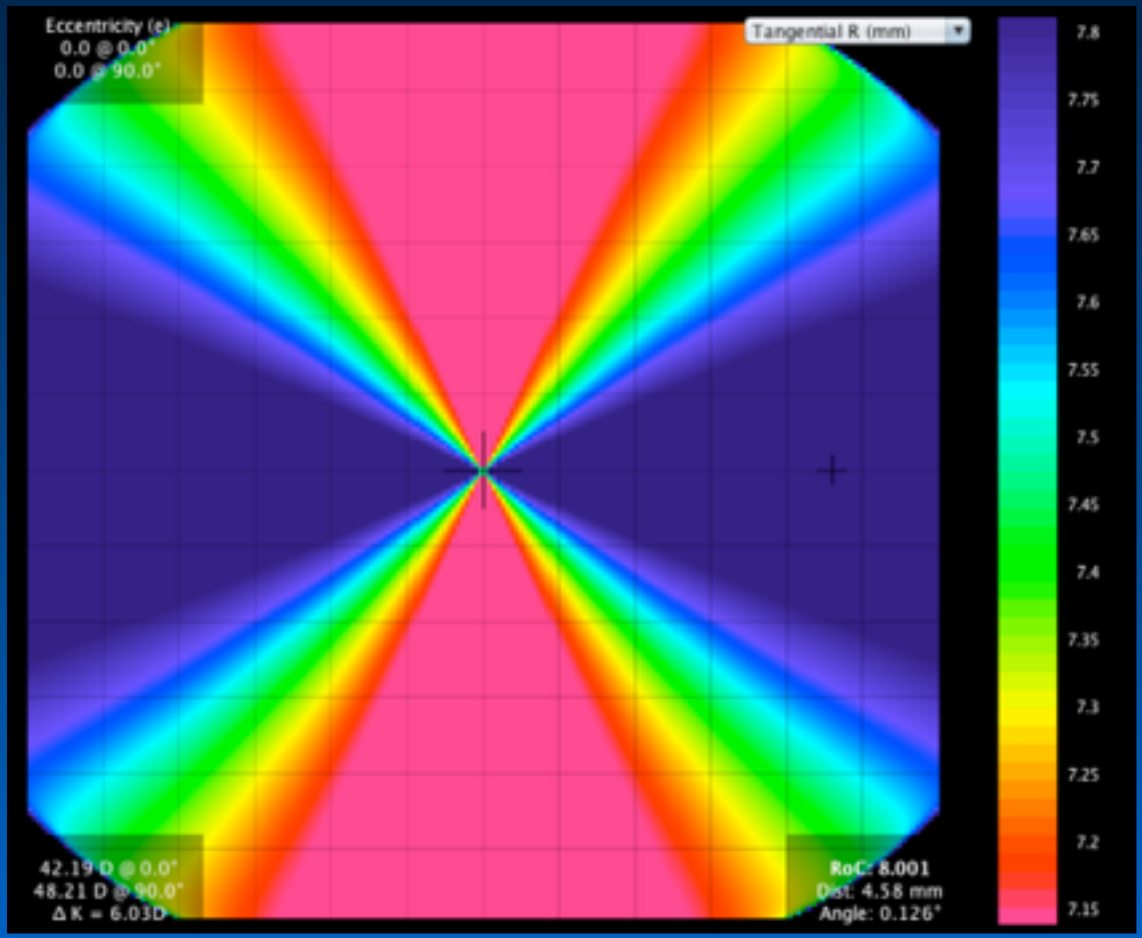
Learning about eccentricity using reference maps



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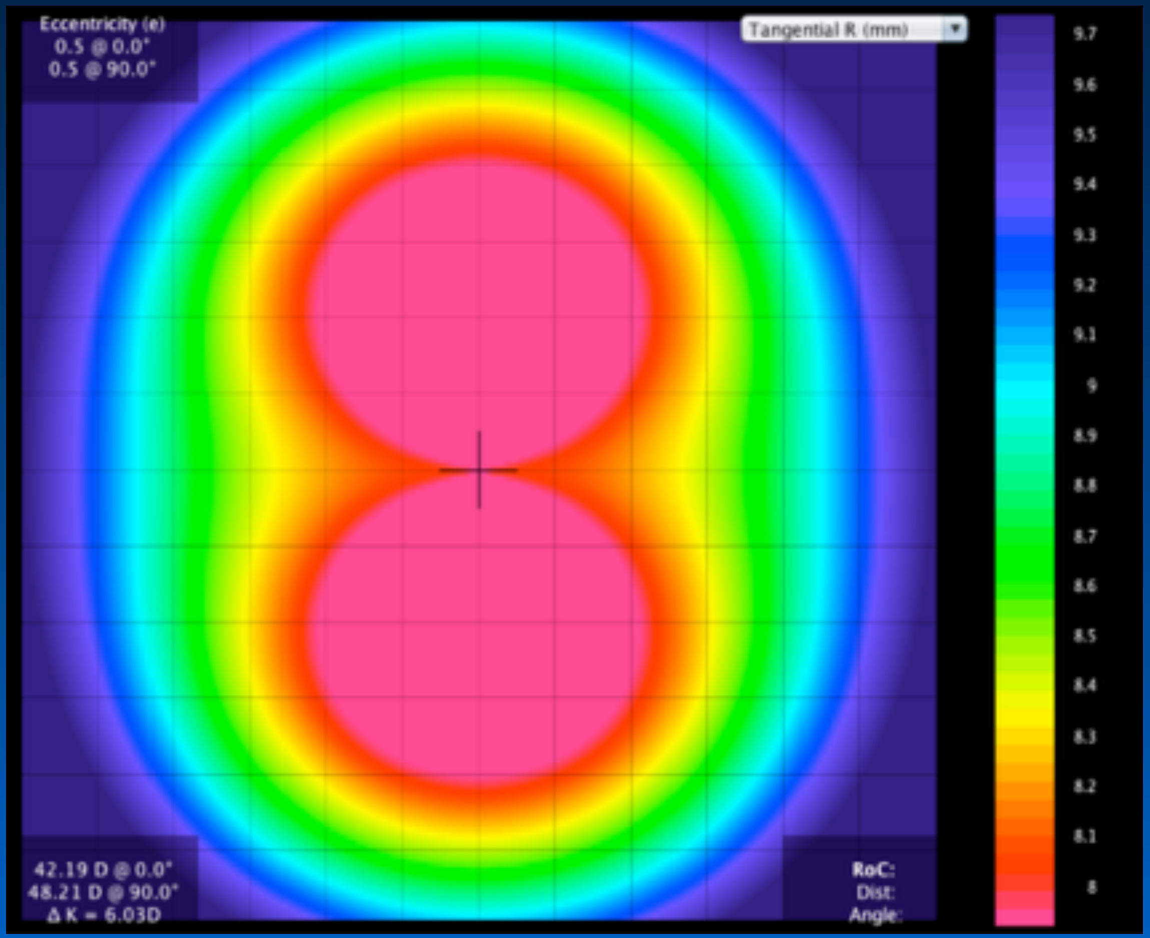

e = 0.5

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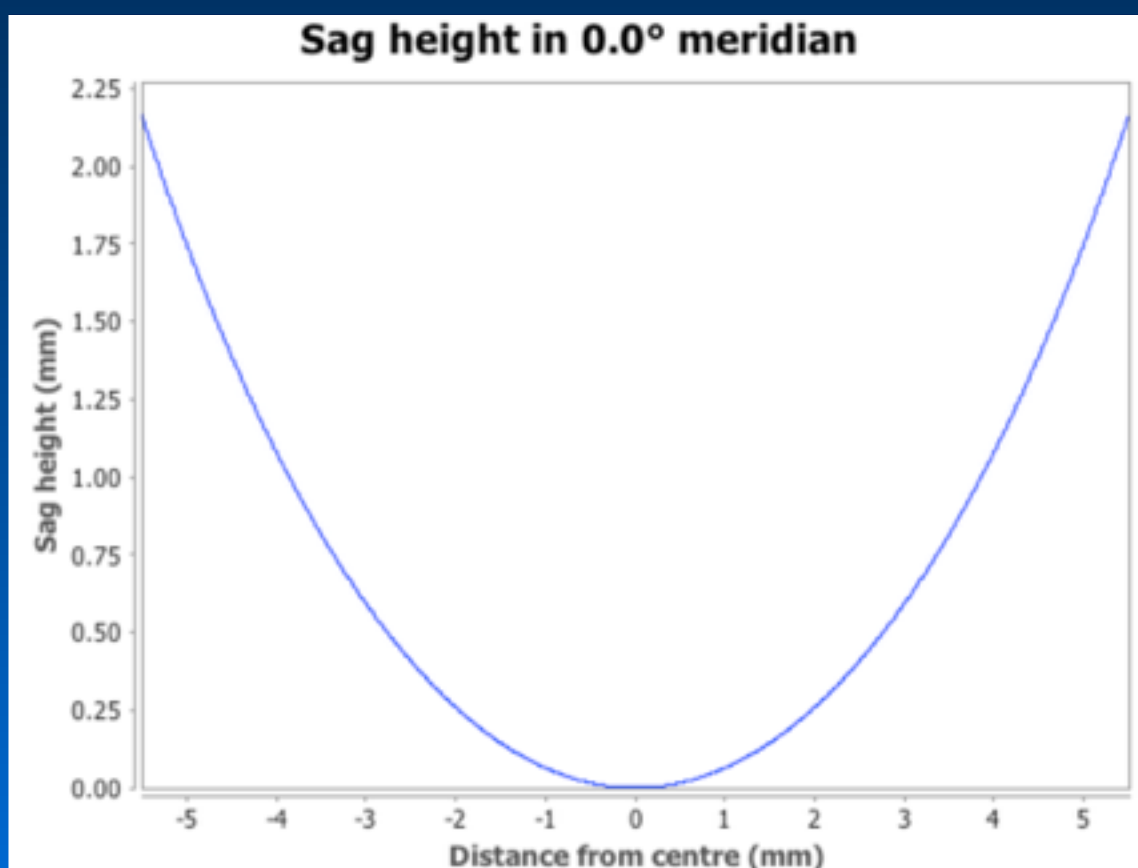
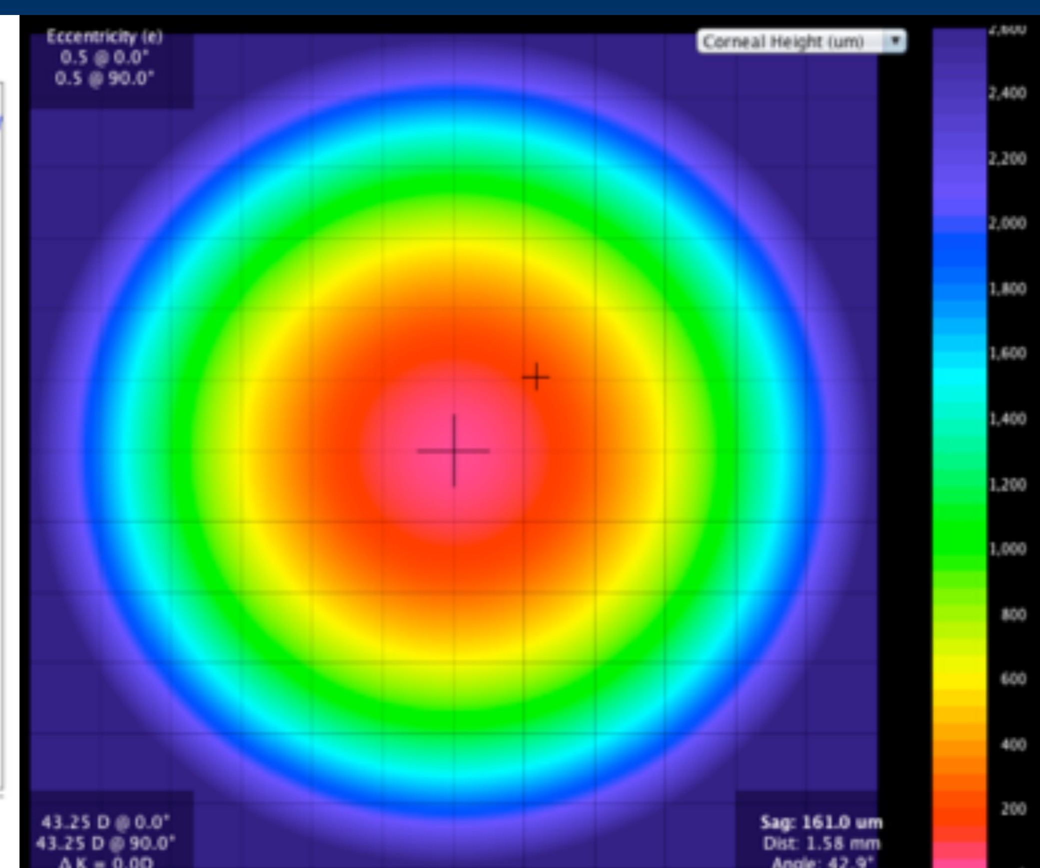
Corneal height

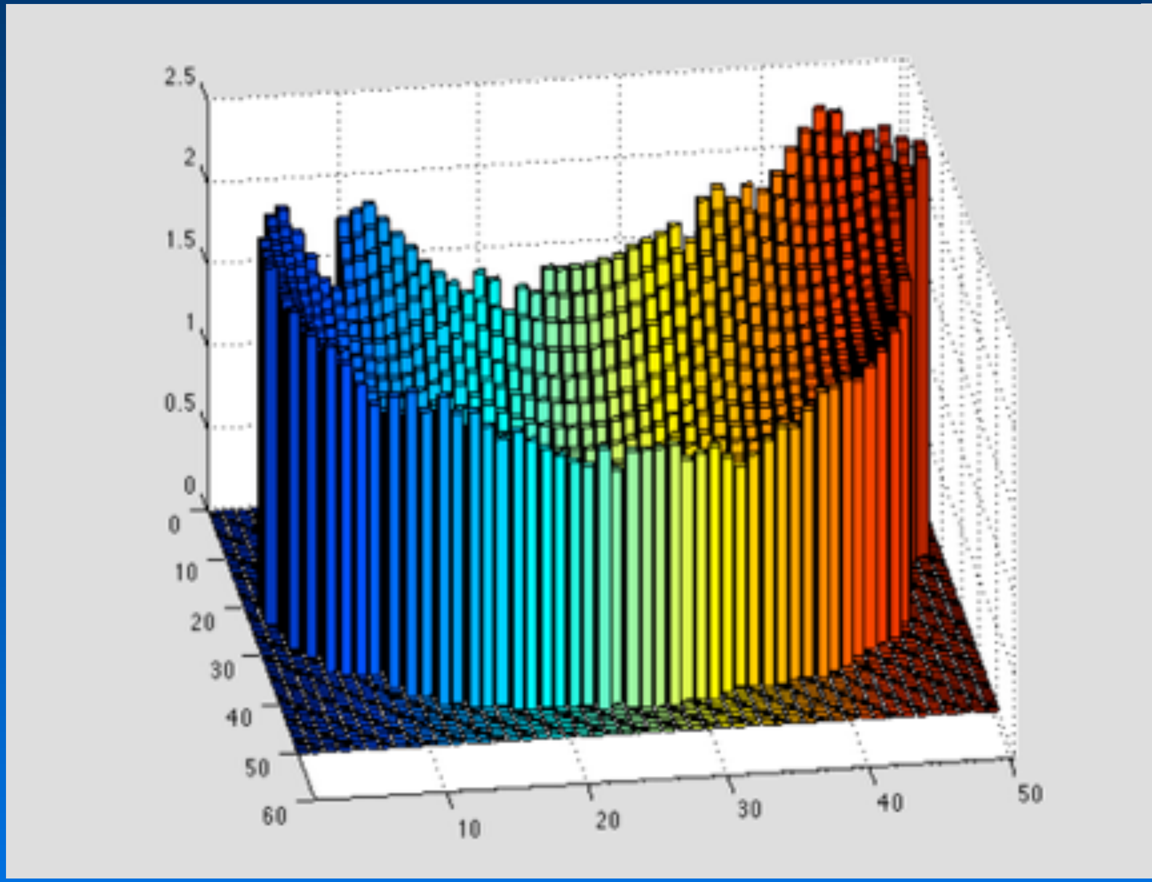
- Axial and Tangential curvature are the important things to look at when analyzing the cornea from a clinical point of view
- To design a custom contact lens, we need to look at corneal height

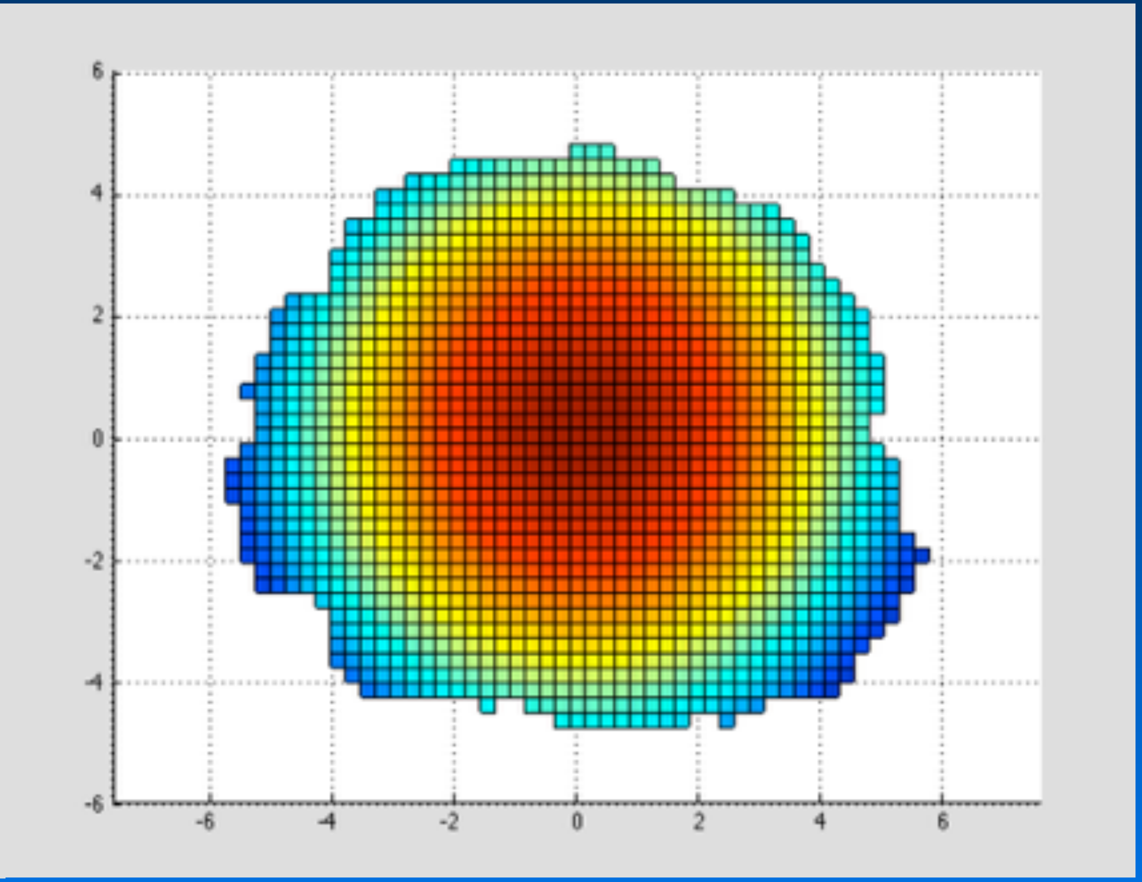




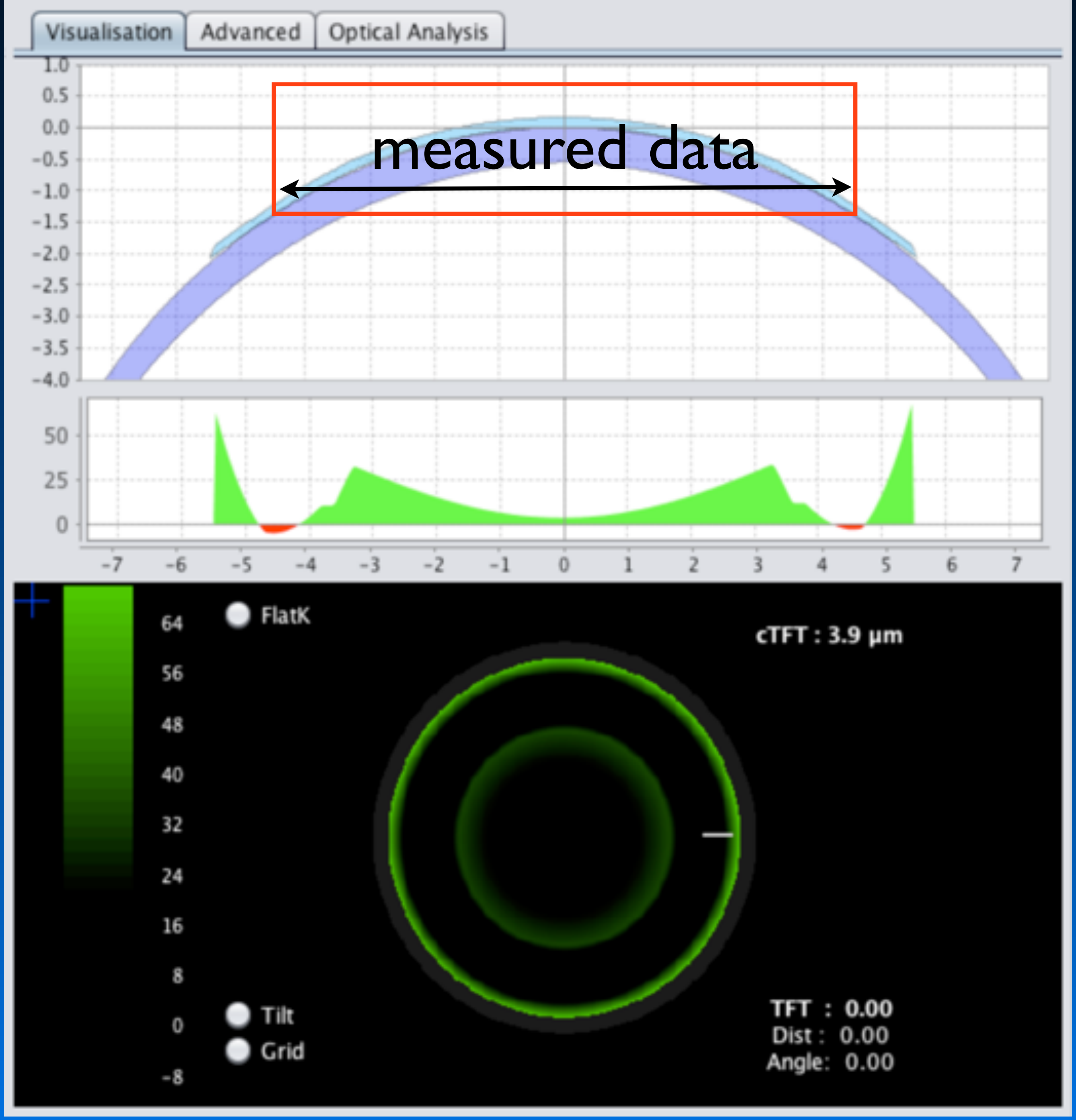
Making corneal height data useful: interpolation and extrapolation

- Corneal height data is available in a 50x50 grid
- There is uneven coverage



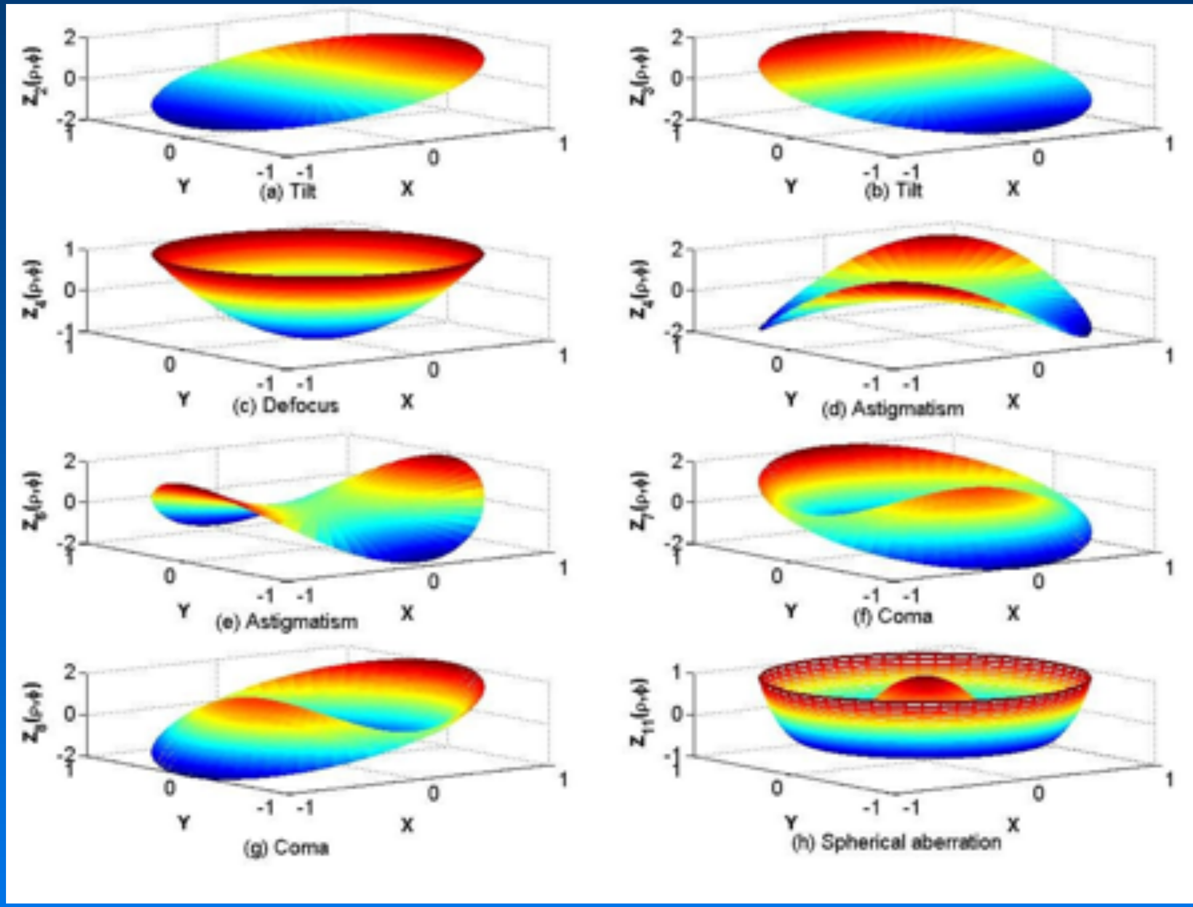


- And the data doesn't extend far enough for us to design a contact lens

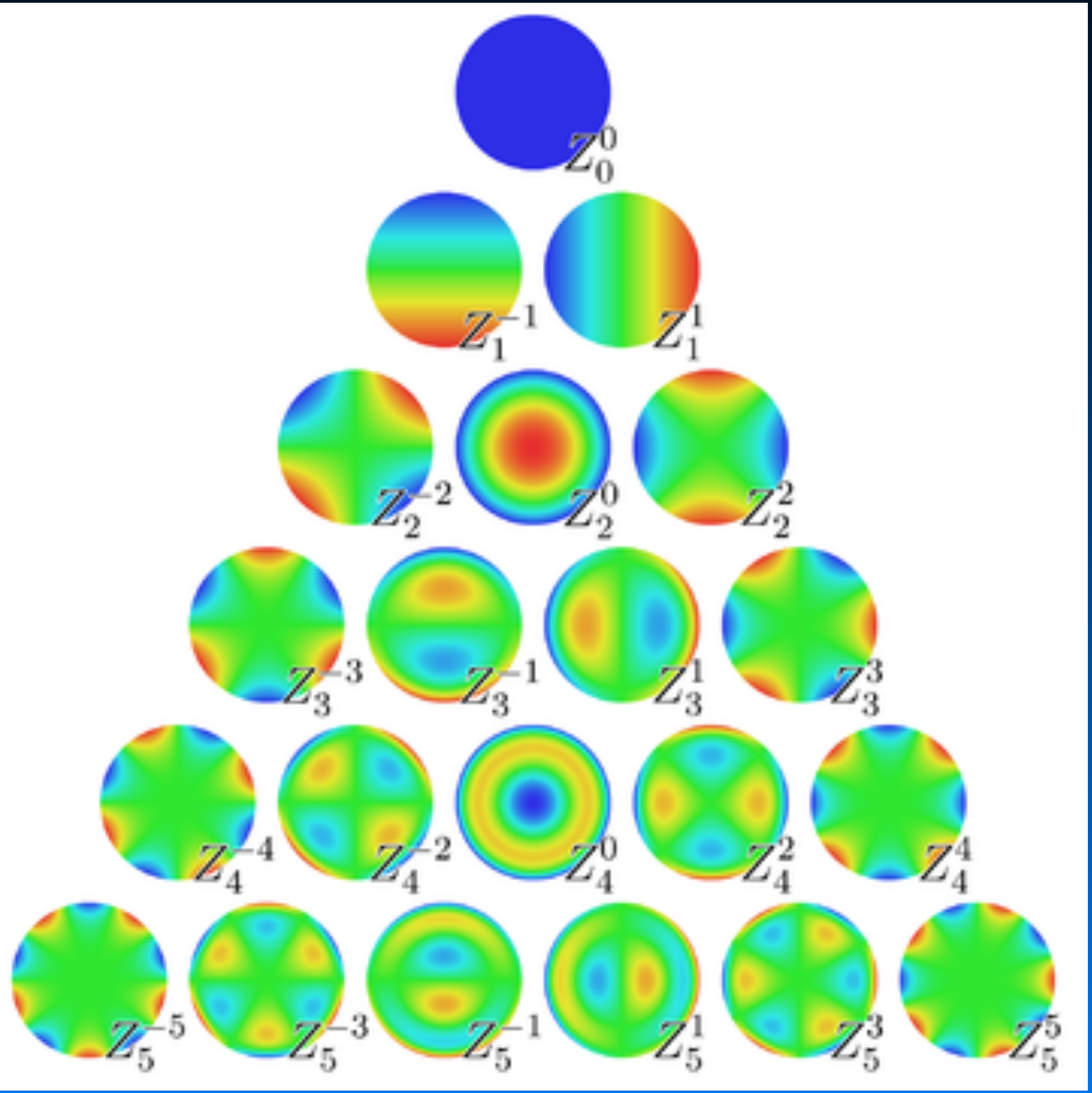


Zernike functions: smoothing data

- We can use Zernike functions to interpolate the central data and extrapolate into the periphery
- We decompose the corneal height data into Zernike basis functions, and then reconstruct the data using the first n basis functions.
- Using a higher n reconstructs the detail in more detail
- So what value of n do we use?



Frequency of Zernike functions



Zernike functions: smoothing data

- Analogy with Fourier analysis

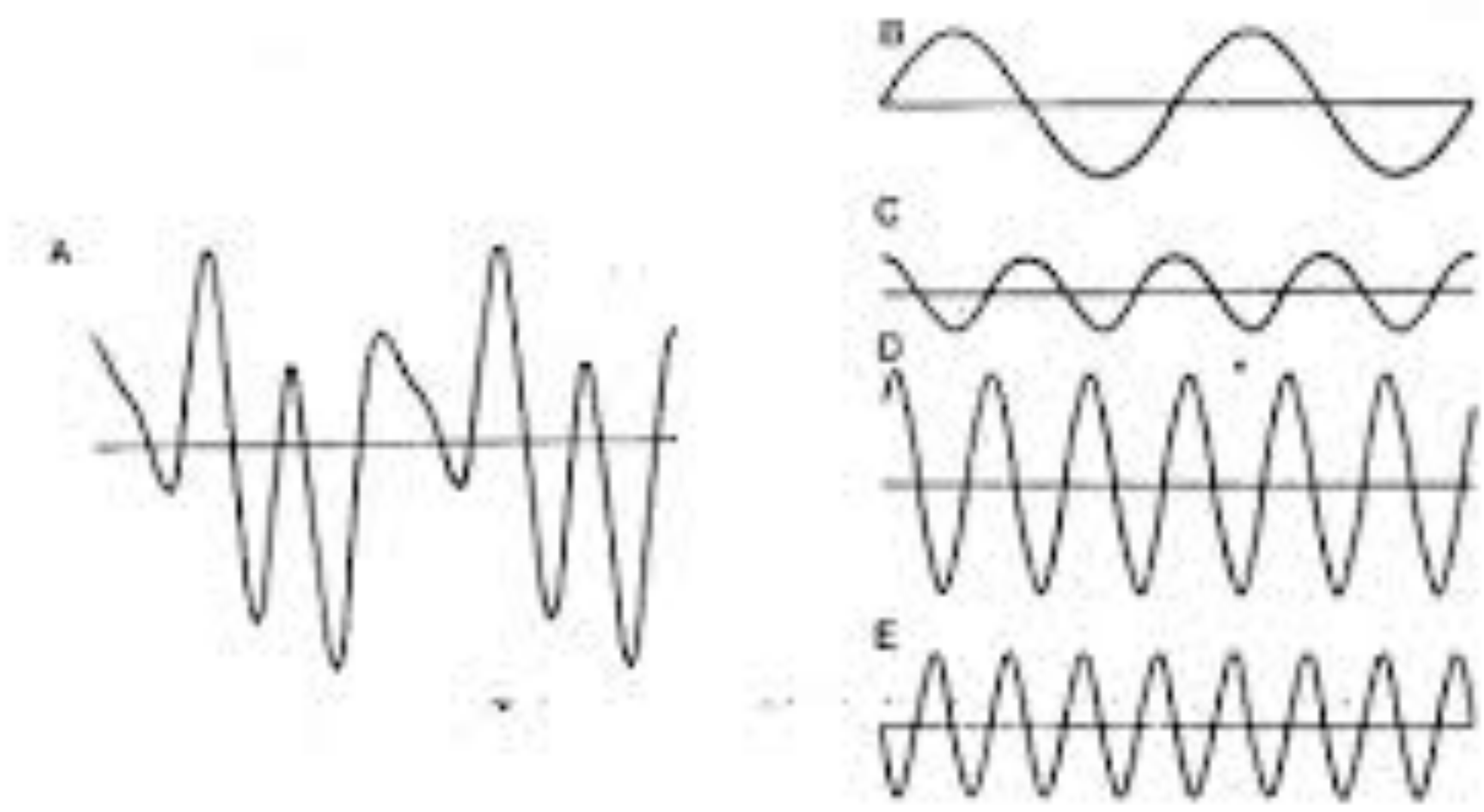
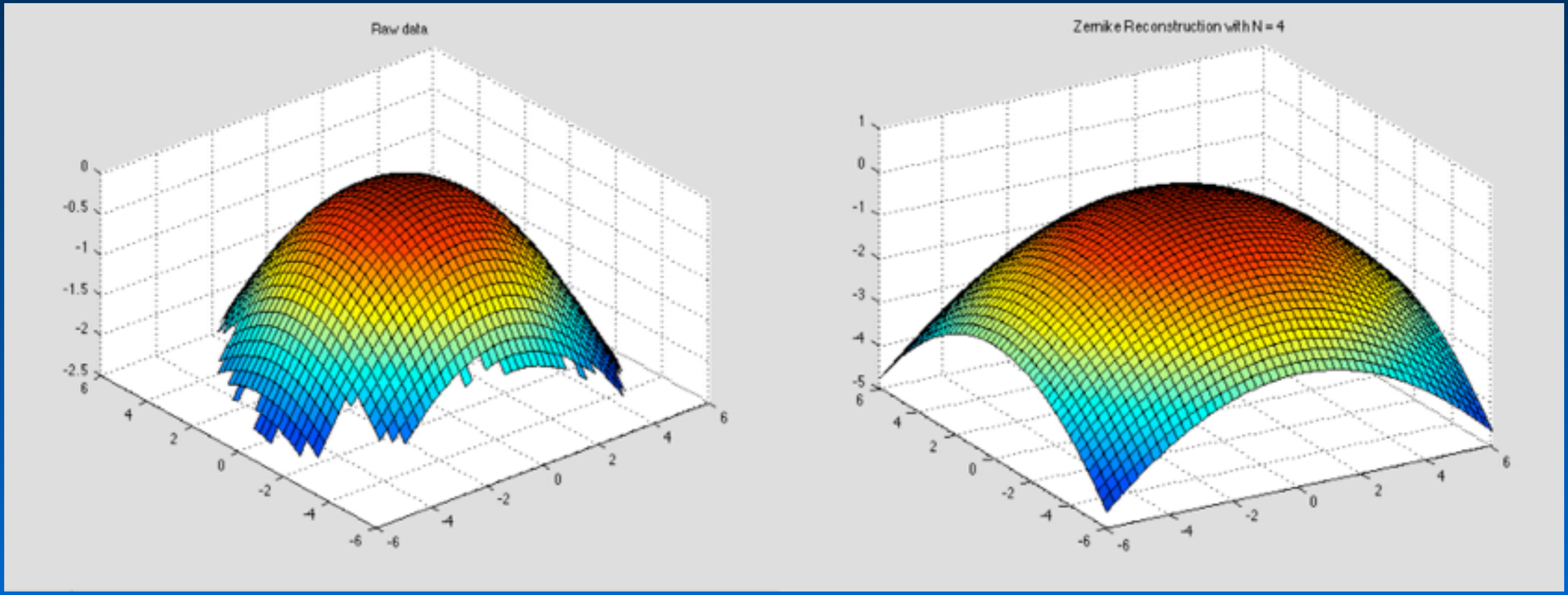


Fig. 1. The wave form A, a complex tone, is in fact the sum of the simple tones B-E. This is an illustration of Fourier's theorem that every vibration of frequency f can be analyzed mathematically into a series of sinusoidal vibrations with frequencies f, $2f$, $3f$, etc. These sinusoidal vibrations are called the harmonics.

Choosing n

- High frequency Zernike's in the centre where we have good data
- Lower frequency Zernike's in the periphery, where the measured data is poor



Low frequency periphery