Benha University

Shoubra Faculty of Engineering

Photogrammetry II

Lecture 3: Image measurements and refinements

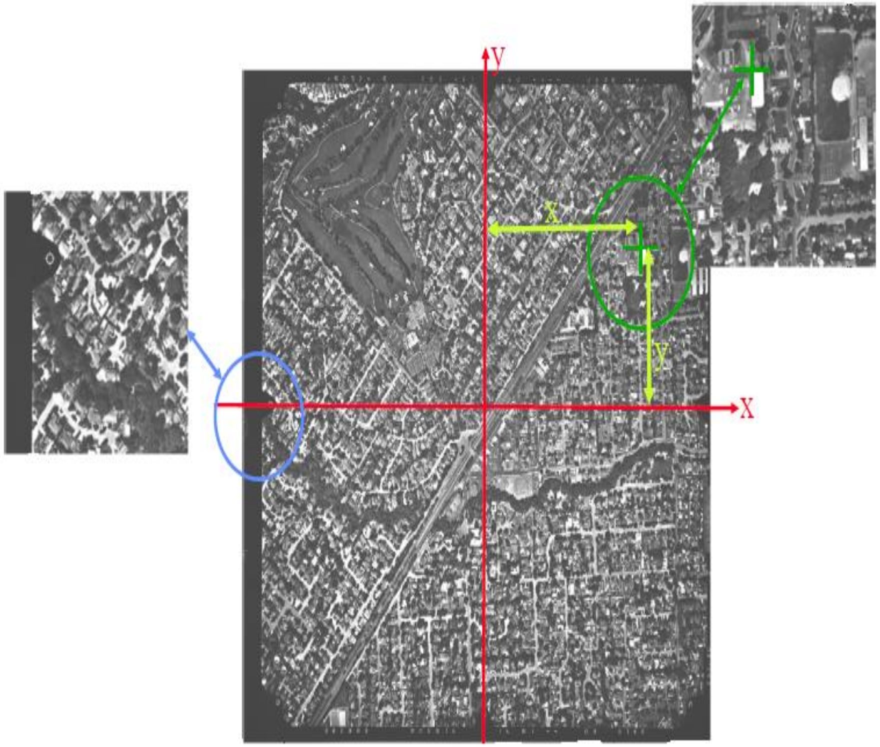
Dr. Eng. Hassan Mohamed Hassan

Hassan.hussein@feng.bu.edu.eg

Geomatics Department

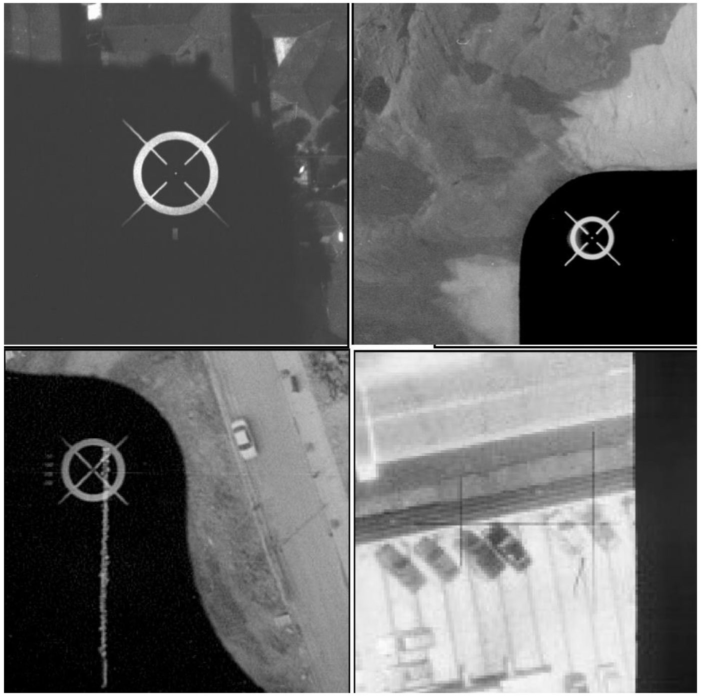
What you learn from this lecture

1. Coordinate system for image measurement .
2. Photographic measurement using comparators.
3. Radial Lens distortion
4. Atmospheric refraction distortion.
5. Earth curvature distortion.



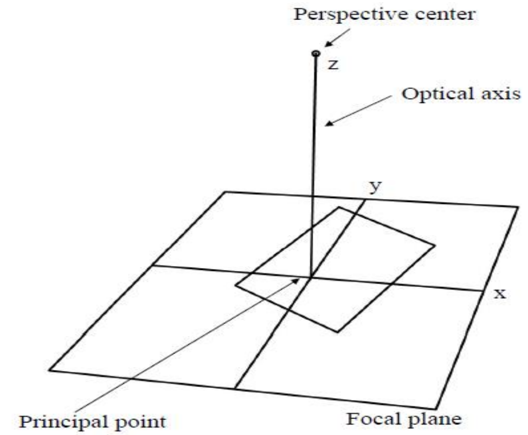
Fiducial Marks

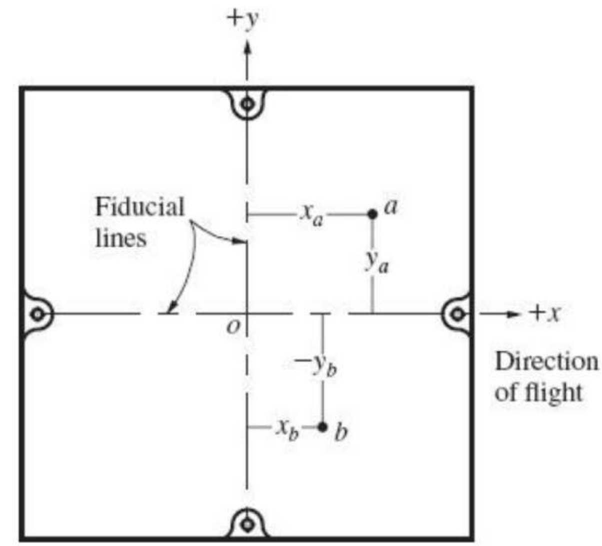
- Fiducial marks are small targets on the body of metric cameras.
- Their positions relative to the camera body are known through a calibration procedure.
- They define the image coordinate system.
- In that system, the position of the perspective center is known.



Coordinate system for image measurement

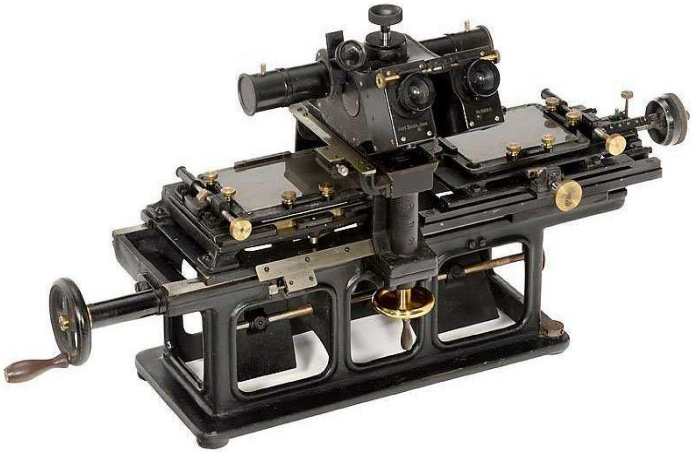
- Metric camera with *FM* rectangular axis system by joining *FM* is commonly adopted.
- The x axis parallel and positive in the direction of flight.
- The positive y axis is 90°, from positive x.
- The origin of the coordinate system is the intersection of F.M lines.
- Position of any image point is given by its rectangular coordinates xa and ya.
- *xa* is perpendicular distance from y axis to a. *ya* is perpendicular distance from x axis to a.

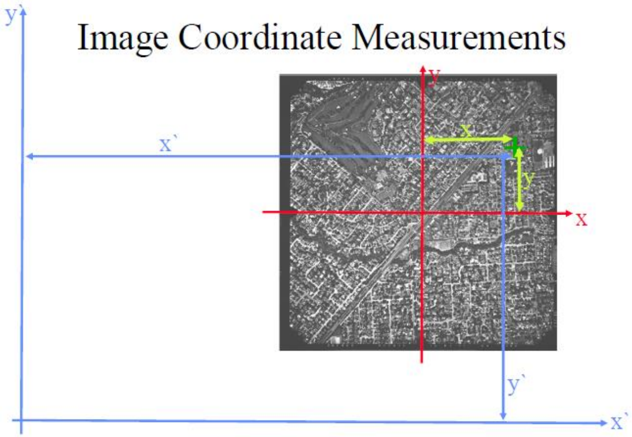




Photographic measurement using comparators

- Comparators are highly accurate machines for measuring the xy-coordinates of selected points in the image plane
- Stereo-comparators: coordinates are measured in a stereo-pair simultaneously.
- The machine/comparator coordinates are reduced to image coordinates (i.e., relative to the image coordinate system)



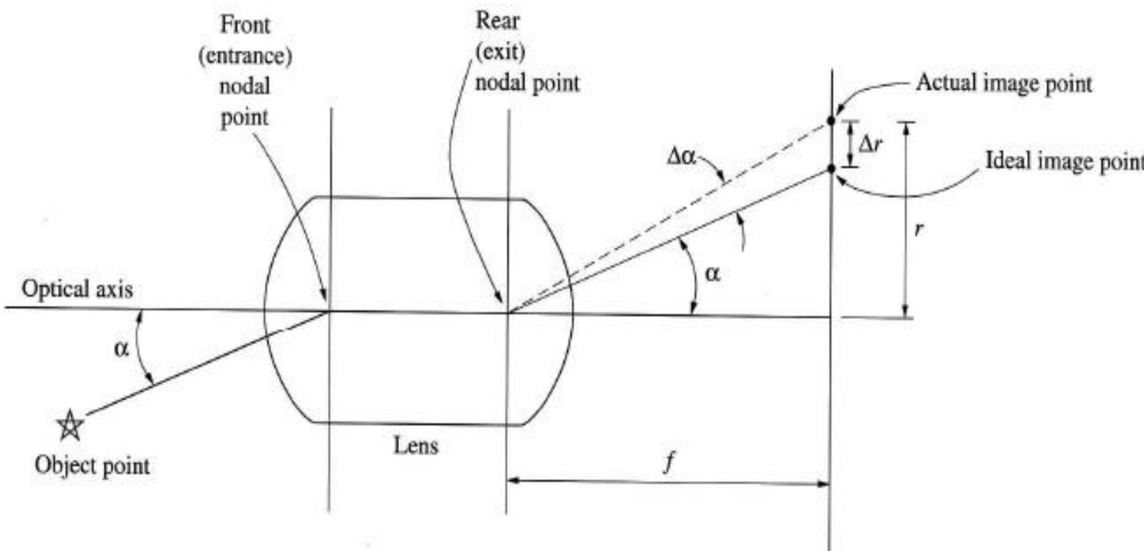


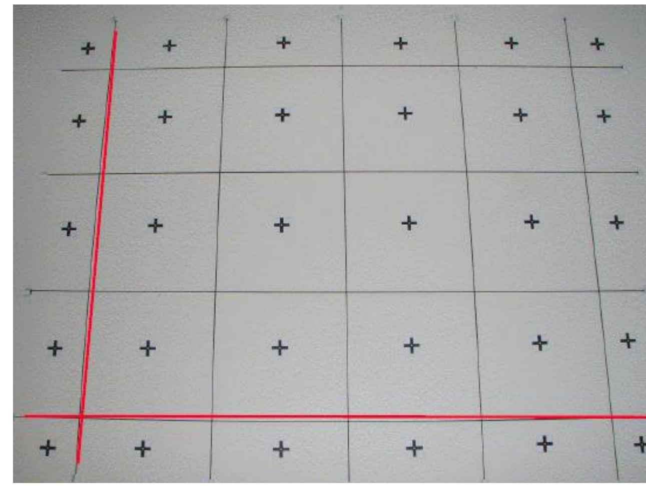
Comparator coordinates (x`, y`) → Image coordinates (x, y)

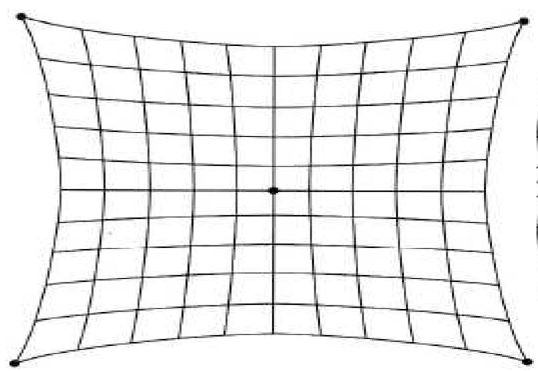
Radial Lens Distortion

- The light ray changes its direction after passing through the perspective center.
- Radial lens distortion is caused by:
- Large off-axial angle
- Lens manufacturing flaws
- Radial lens distortion occurs along a radial direction from the principal point
- Radial lens distortion increases as we move away from the principal point

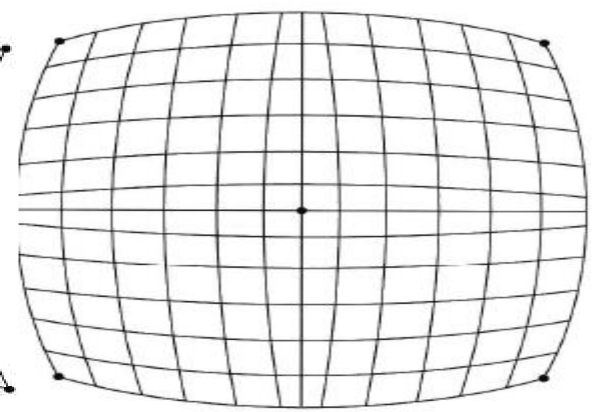
Radial Lens Distortion







Positive

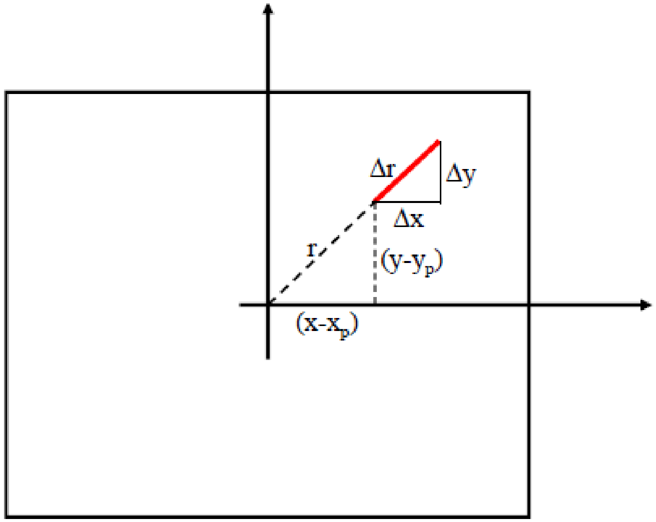


Negative

Radial Lens Distortion

- Radial lens distortion, Δr as a function of r, is available in the camera calibration certificate in either one of the following forms:

1. Graphical form
2. Tabular form
3. Polynomial coefficients



$$\Delta r = k_1 r_1 + k_2 r_3 + k_3 r_5 + k_4 r_7$$

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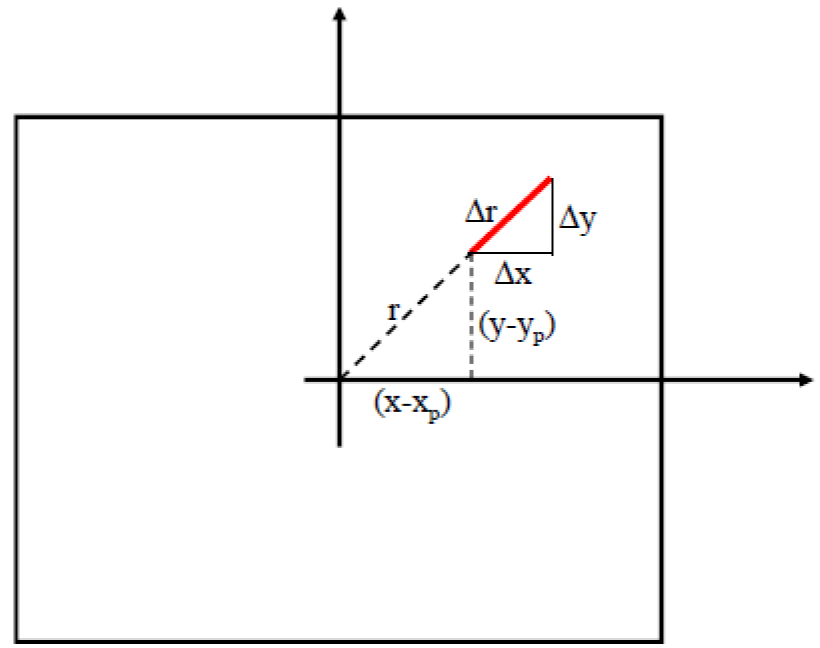
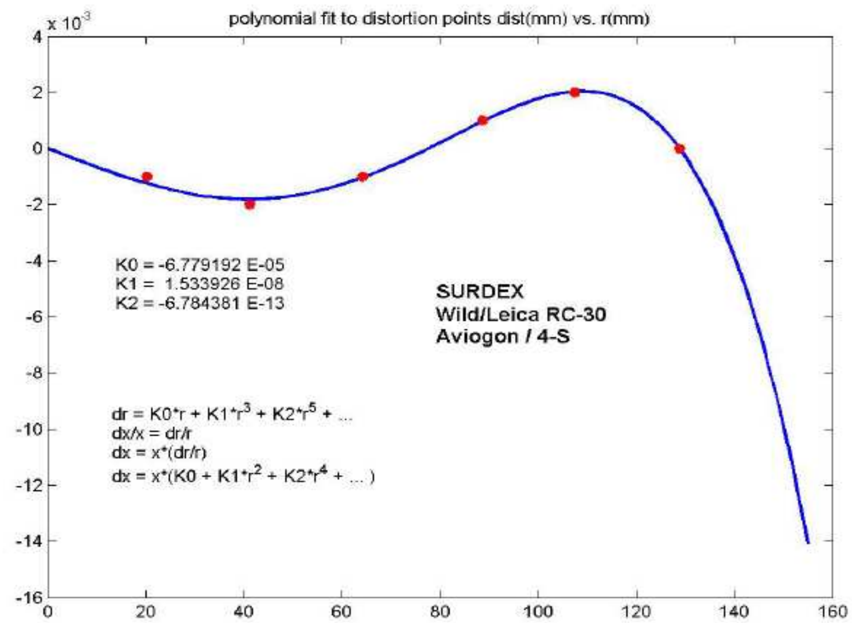


$$\Delta r = k_1r_1 + k_2r_3 + k_3r_5 + k_4r_7$$

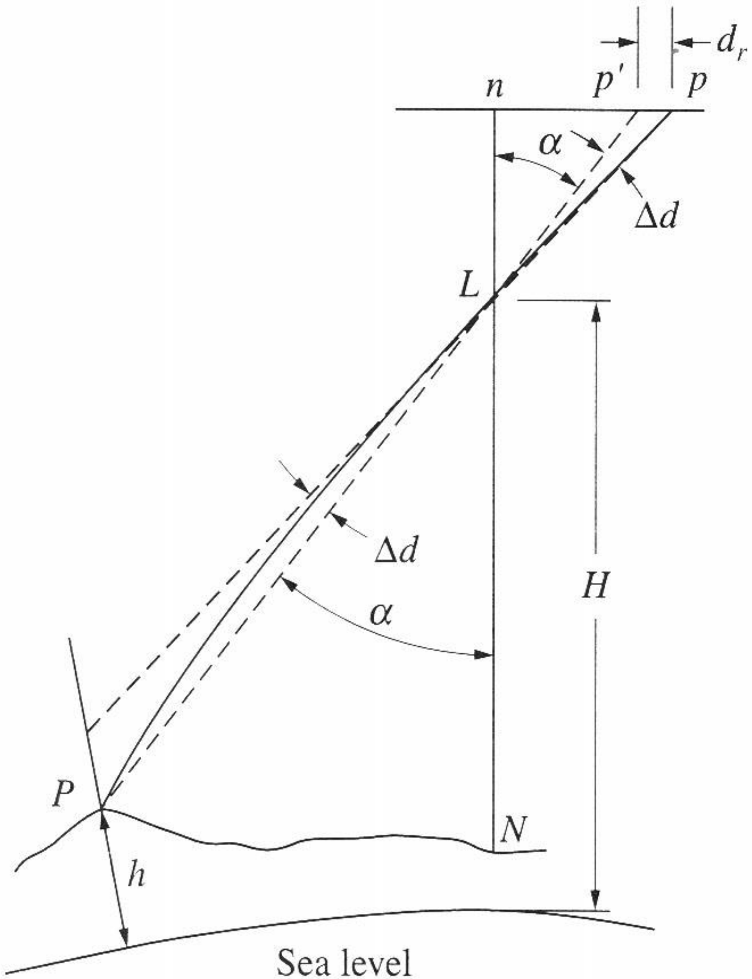
Radial Lens Distortion

Symmetric Radial Distortion Parameters		Decentering Distortion Parameters		Calibrated Principal Point	
k_0	0.5493×10^{-4}	p_1	$-0.7953 \times 10^{-7}\ mm^{-1}$	x_p	0.010 mm
k_1	$-0.5984 \times 10^{-8}\ mm^{-2}$	p_2	$0.1018 \times 10^{-6}\ mm^{-1}$	y_p	-0.001 mm
k_2	$0.1053 \times 10^{-12}\ mm^{-4}$	p_3	$0\ mm^{-2}$		
k_3	$0\ mm^{-6}$	p_4	$0\ mm^{-4}$		
k_4	$0\ mm^{-8}$				



Atmospheric Refraction Distortion

- The light ray from the object point to the perspective center passes through layers with different temperature, pressure, and humidity.
- Each layer has its own refractive index.
- Consequently, the light ray will follow a curved not a straight path.
- The distortion occurs along the radial direction from the nadir point.
- It increases as the radial distance increases. is always negative -

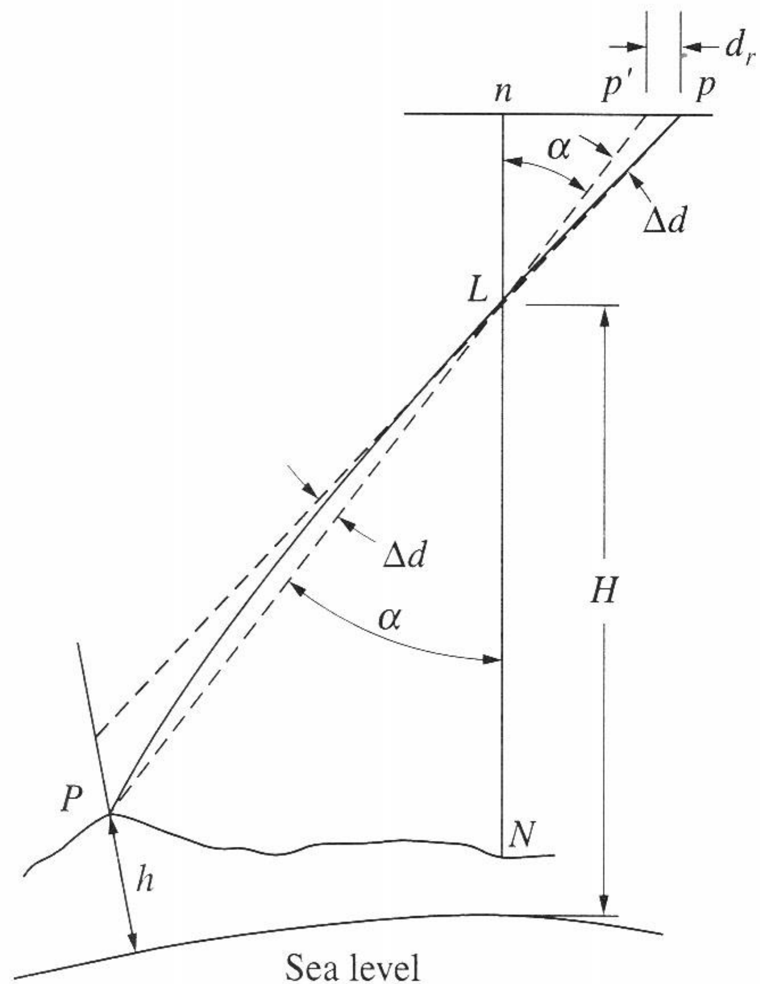


Atmospheric Refraction Distortion

- $\Delta r = k\, r\,(1 + \frac{r2}{f2})$
- K is the atmospheric refraction coefficient.

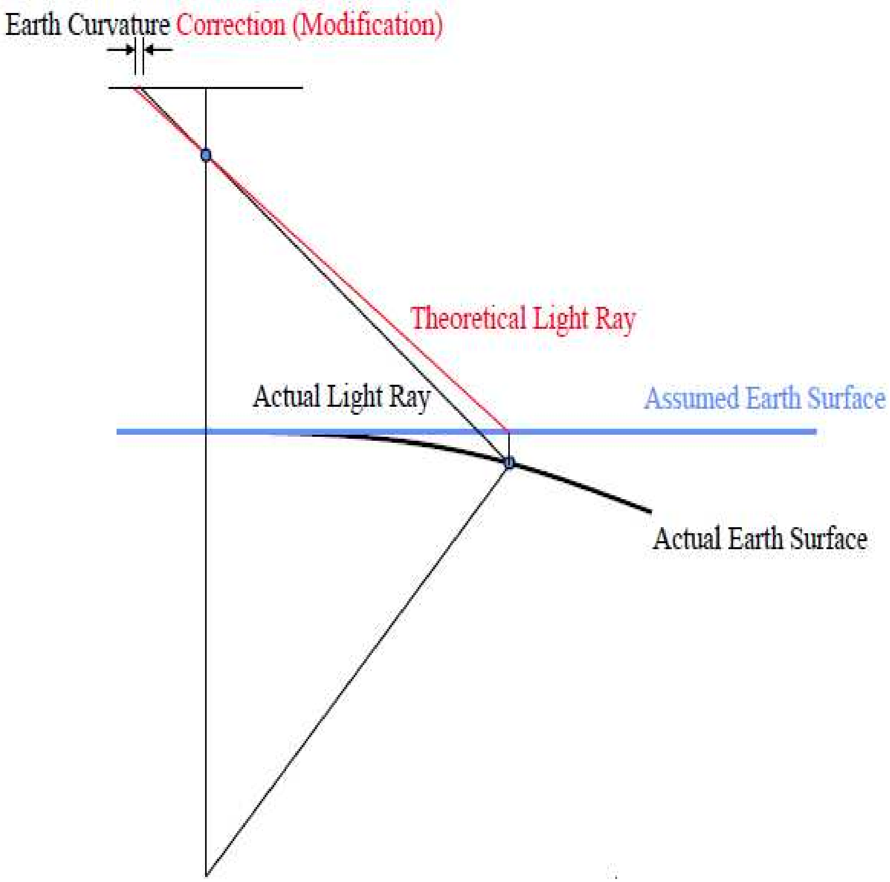
$$k = 0.00241 \left\{ \frac{Z_o}{Z_o^2 - 6\,Z_o + 250} - \frac{Z^2}{Z_o(Z^2 - 6\,Z + 250)} \right\}$$

- Zo is the flying height in km
- Z is the ground elevation in km
- $Xc = X\,(1 - \frac{\Delta r}{r})$, $Yc = Y\,(1 - \frac{\Delta r}{r})$



Earth Curvature Distortion

- The Earth surface as reconstructed from the imagery is a spheroid.
- The Earth surface as defined by the GCP is flat
- we distort the image coordinates in such a way that the Earth surface as reconstructed from the imagery is flat. Δr is always positive +



$$\Delta r = \frac{H\, r^3}{2\, R f^2}$$

Earth Curvature Distortion

$$\Delta r = \frac{H\, r^3}{2\, R\, f^2}$$

- H flying height,
- r radial distance from the principal point,
- R radius of the Earth (6370 Km),
- F focal length

- rc = r + Δr
- $Xc = X\,(1 - \frac{\Delta r}{rc})$, $Yc = Y\,(1 - \frac{\Delta r}{rc})$

Supplementary files:

- https://www.youtube.com/watch?v=Eo0MnUahGHM
- Elements of Photogrammetry with Applications in GIS, Fourth Edition. Paul R. Wolf, Bon A. Dewitt, Benjamin E. Wilkinson, 2014 McGraw-Hill Education

Thanks

Dr.Eng. Hassan Mohamed