Lectures Remote Sensing

GEOMETRICAL ASPECTS AND MAPPING OF RS

dr.ir. Jan Clevers

Centre of Geo-Information

Environmental Sciences

Wageningen UR

Geometrical Aspects and Mapping of RS

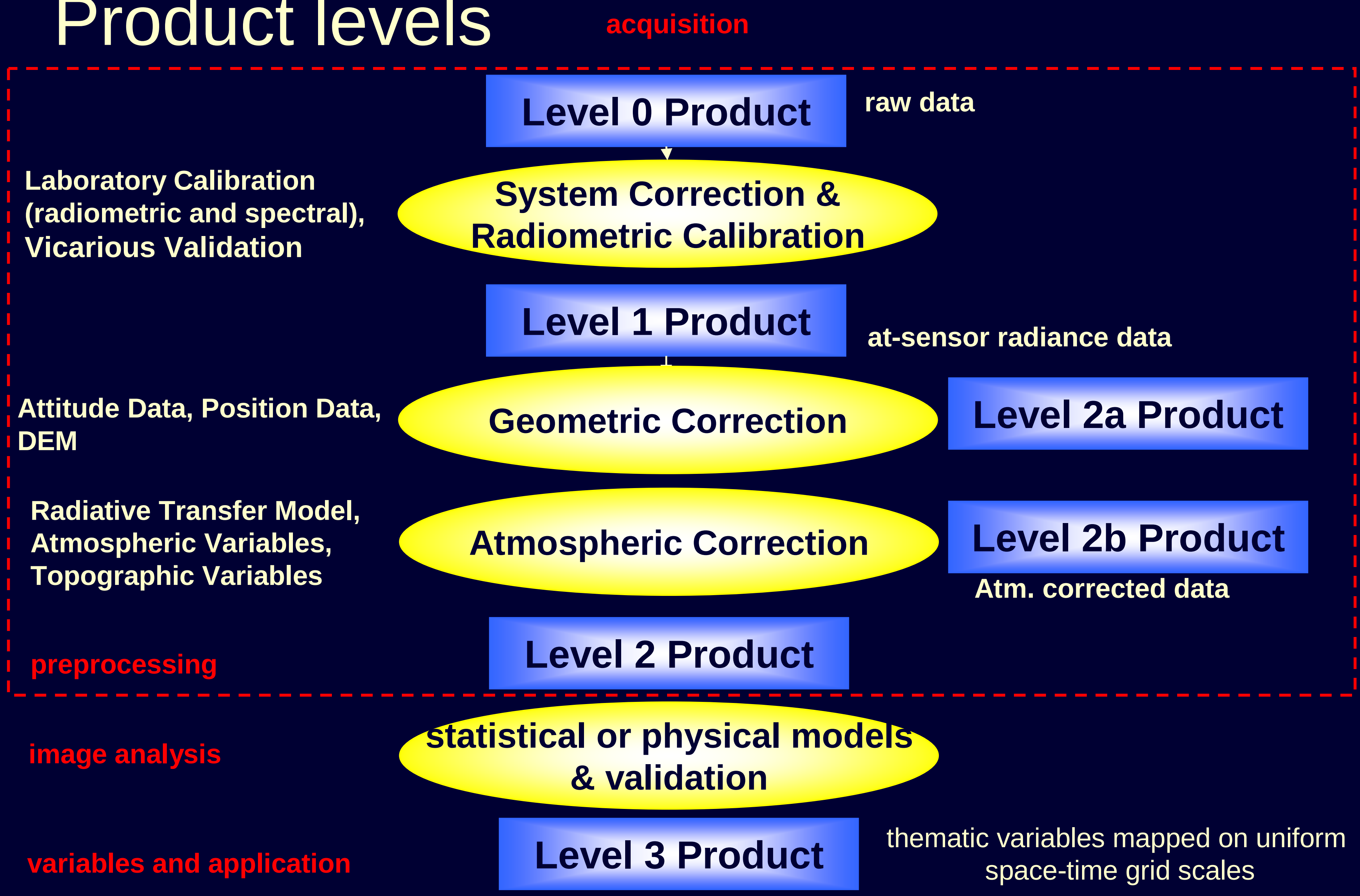
- Importance of geometry
- Image matching
- Resampling

(L&K section 7.2)

- Sensor geometry

(L&K sections 5.6 and 5.7)

Product levels



Why Is Geometry Important?

Mutual comparison of images

- multi-spectral
- multi-sensor
- multi-level
- multi-temporal

Comparison with and use of existing data (maps, GIS) for:

- interpretation
- mapping (geometry, thematics)
- building data base (selection, conversion, aggregation, etc)

GIS Geographical Information System

Well-considered combination of mutually referring **data sets** of various kinds of **position-bound thematic data** (database), software inclusive.

Requirement:
the information layers match geometrically
→ **overlay structure**

GIS file:

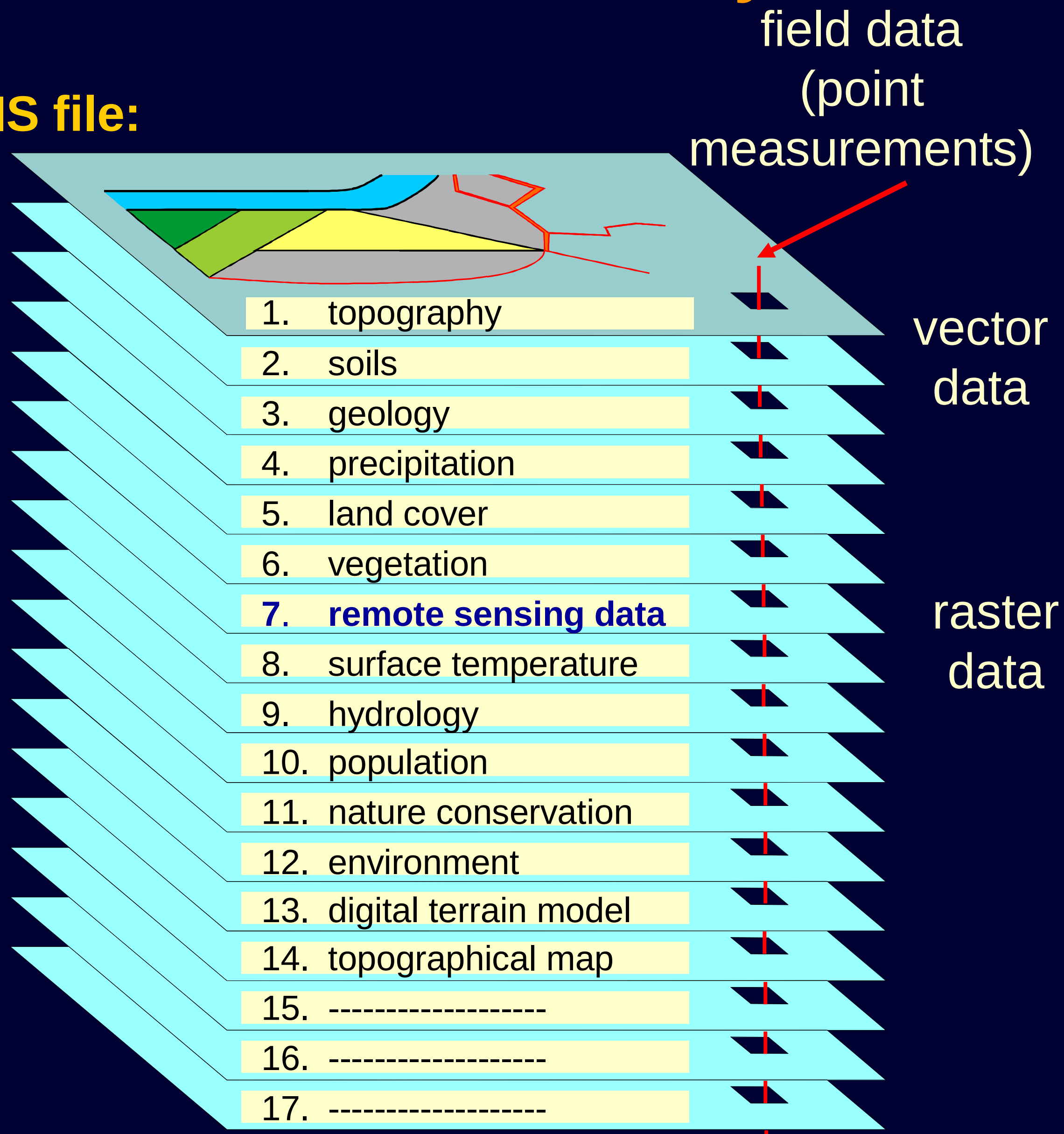


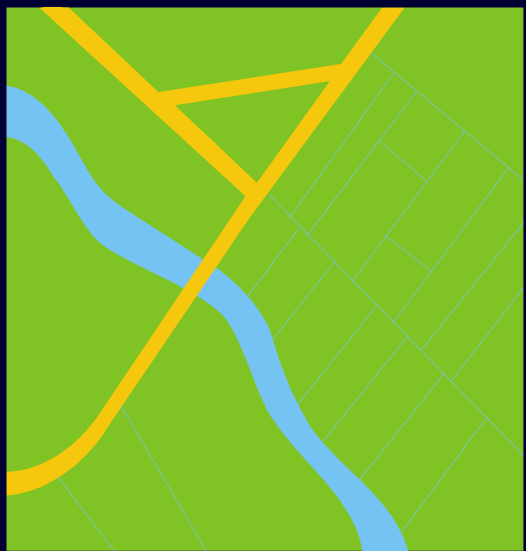
Image Matching

image geometry

(i,j)

map geometry

(x,y)



Master or reference

Image matching
(using control points)

Slave or input

Example airborne Daedalus image

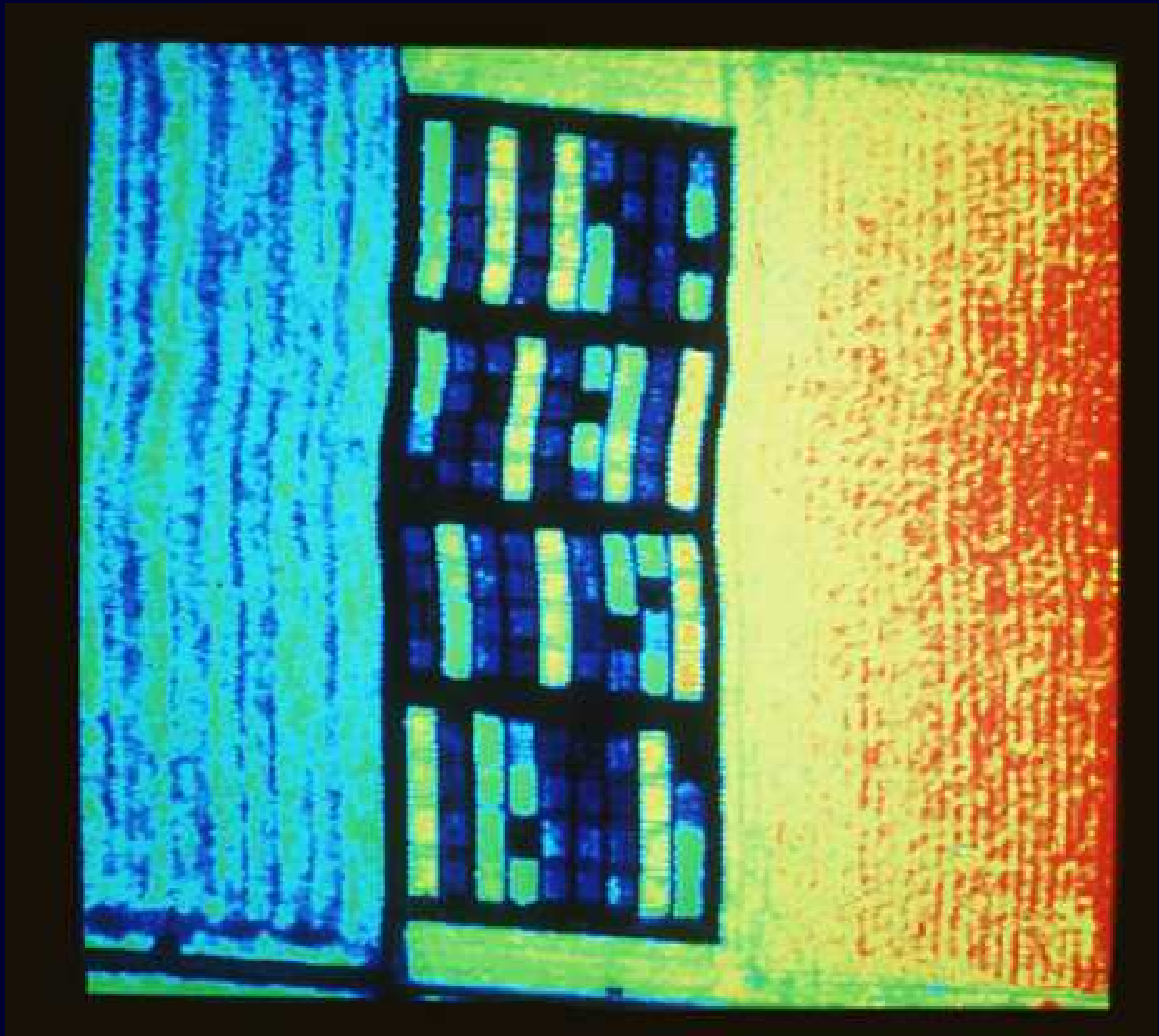
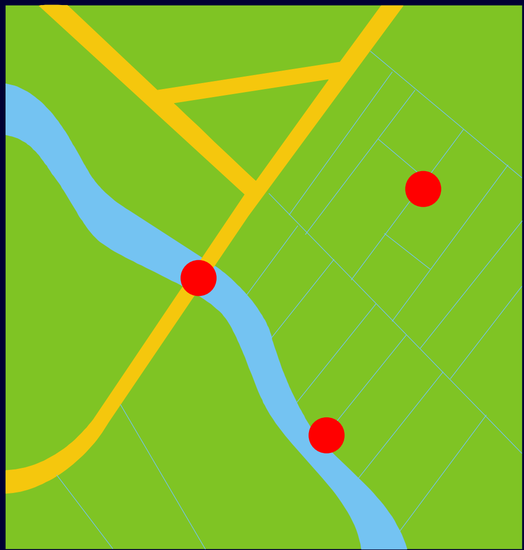
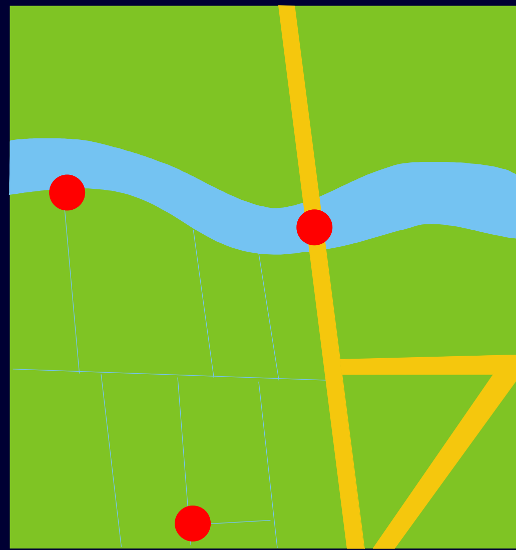
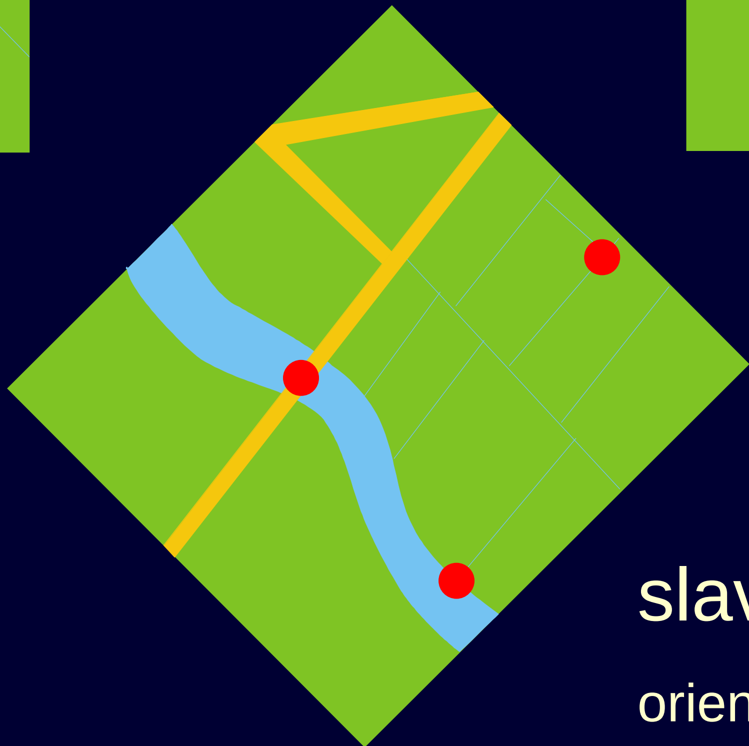


Image Matching -2-



master

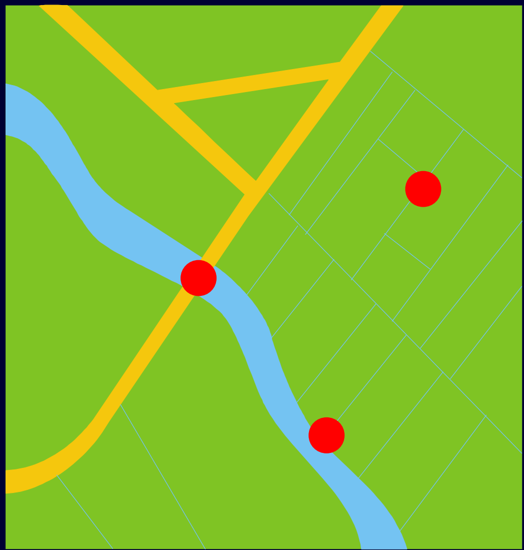


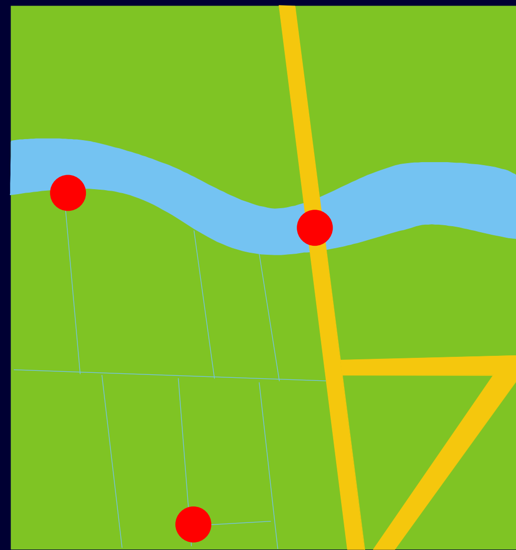


slave

orientated to the master

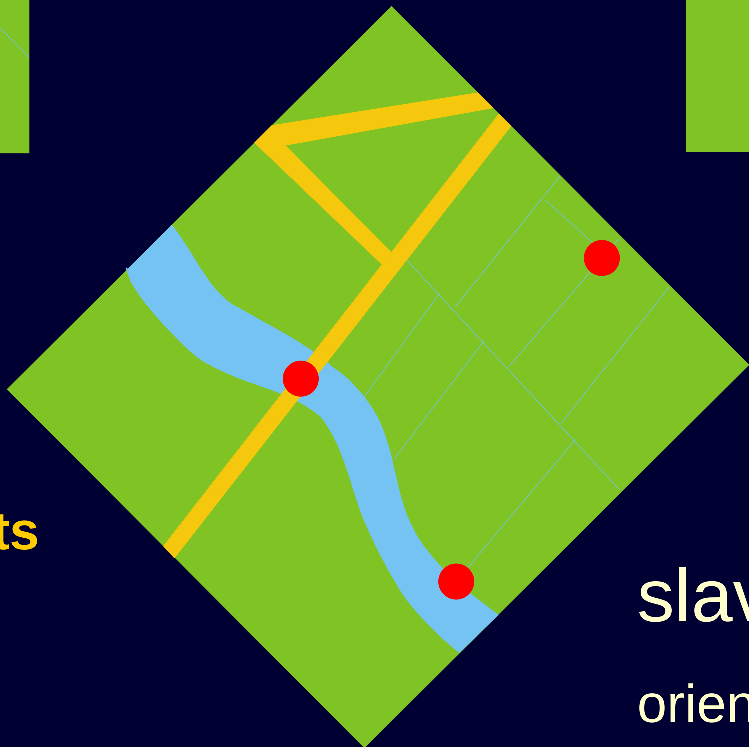
Image Matching -3-





master

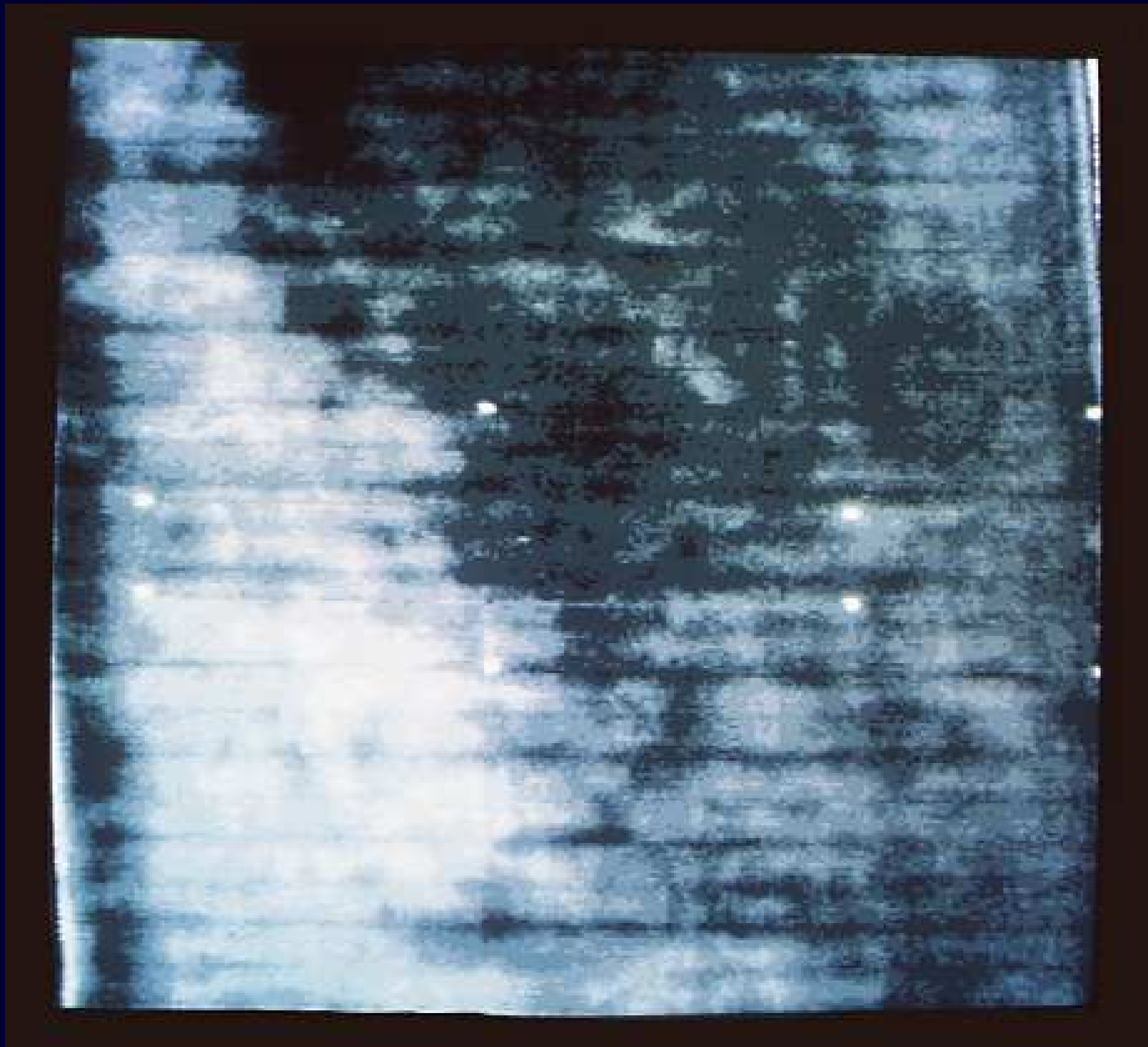
The transformation coefficients are determined using **ground control points** (GCPs)



slave

orientated to the master

GCPs in TIR image



GCP selection in Landsat-TM image

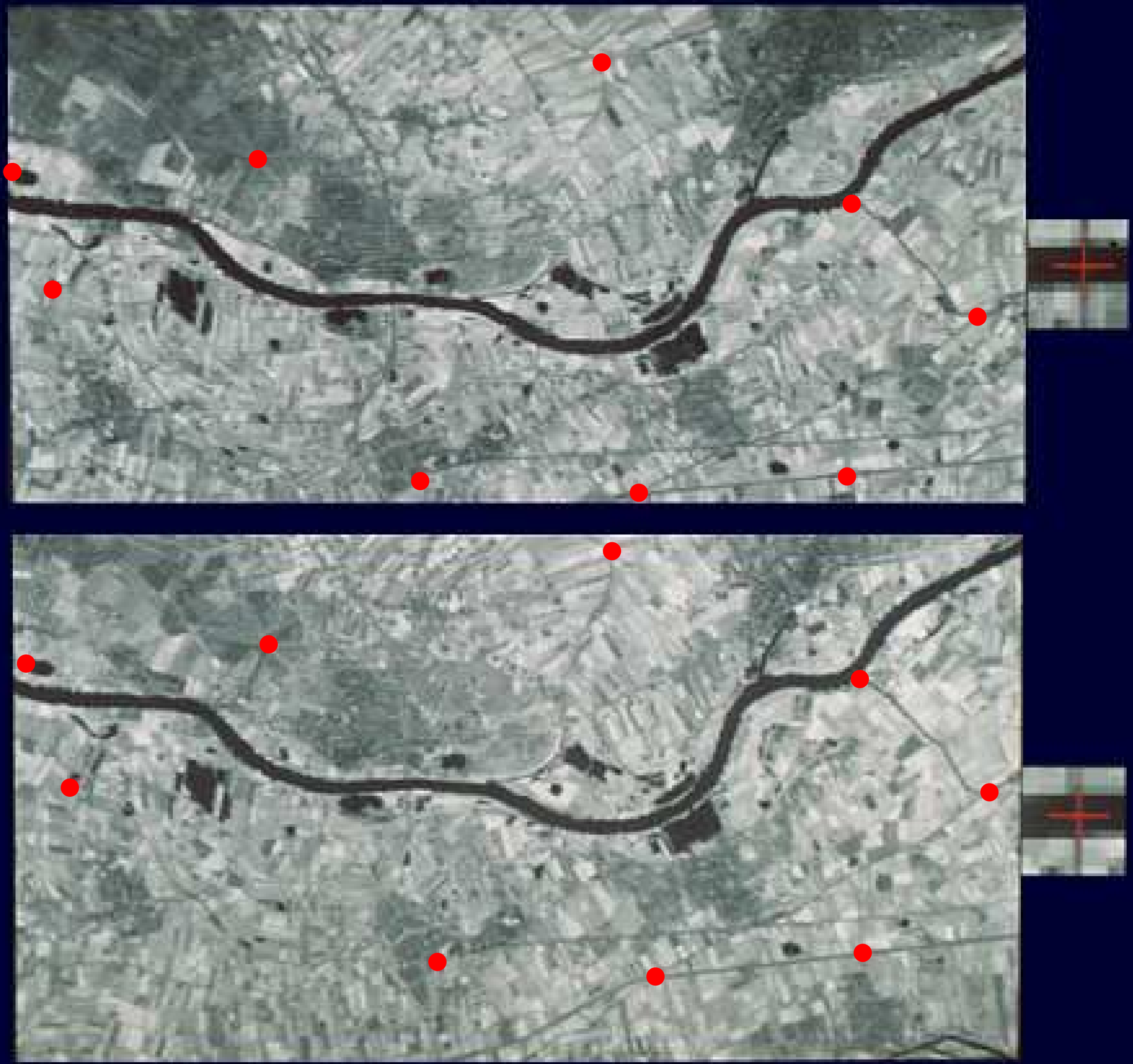
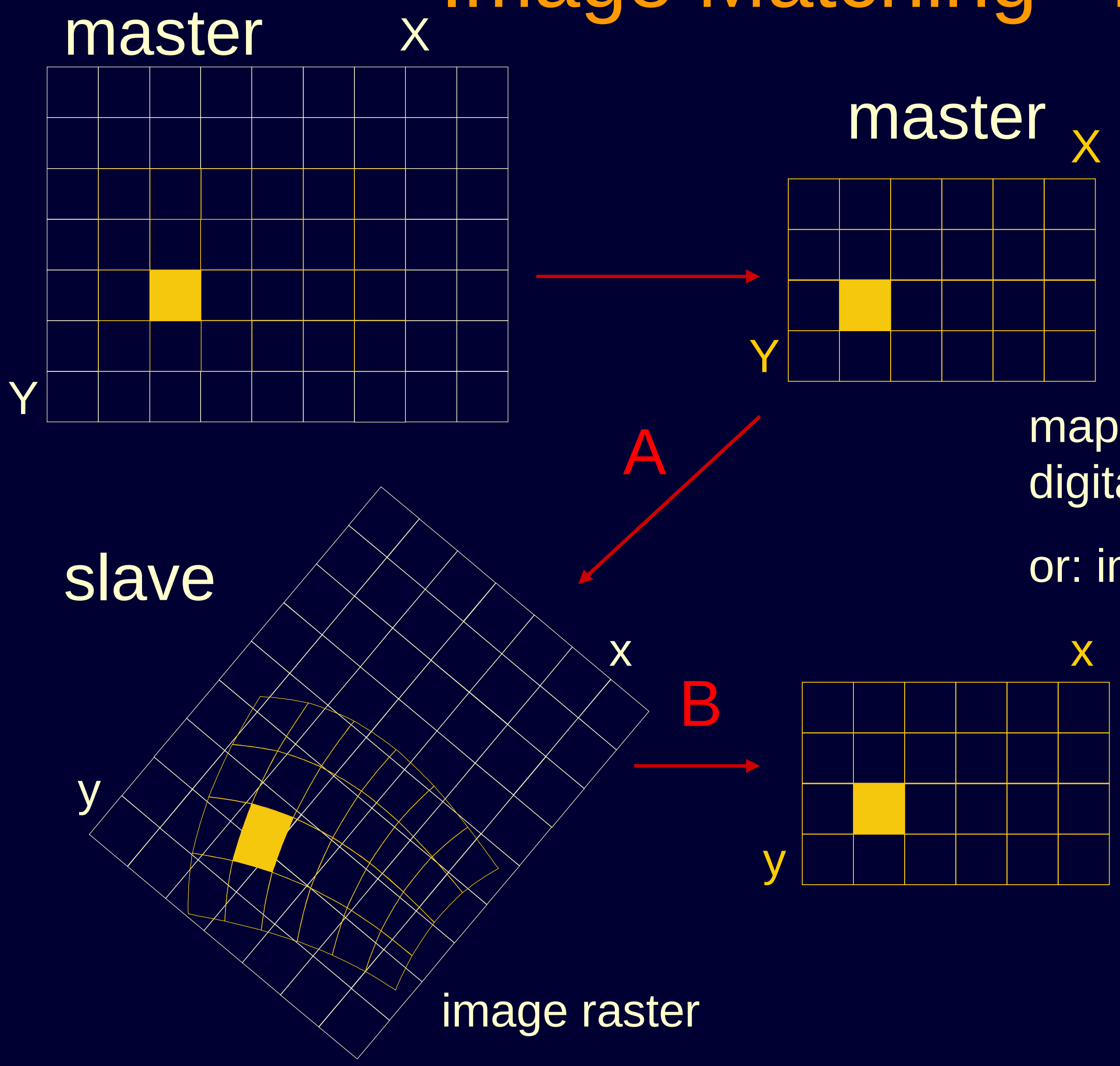


Image matching TM band 4, 1984 (red) and 1986 (green)

Image Matching -4-



map configuration in digital raster format

or: image raster

transformed slave

image raster

or: map configuration

Steps Image Matching

A: Transformation

$$\begin{cases} x = f(X,Y) + u \\ y = g(X,Y) + v \end{cases}$$

- parametric (flight parameters)
- non-parametric (ground control points)

B: Resampling

Transformation

Trend model: transformation using polynomials
(first, second, third order)

$$x = a_1 + a_2X + a_3Y + a_4X^2 + a_5XY + a_6Y^2 + \ldots + u$$
$$y = b_1 + b_2X + b_3Y + b_4X^2 + b_5XY + b_6Y^2 + \ldots + v$$

↑ residuals

Determination of the coefficients $a_1 \ldots a_{10}$, $b_1 \ldots b_{10}$ using ground control points:

$$\underbrace{\begin{pmatrix} 1\ X_1\ Y_1 & X_1^2\ X_1Y_1\ Y_1^2 & X_1^3\ X_1^2Y_1\ X_1Y_1^2\ Y_1^3 \\ & & \\ 1\ X_n\ Y_n & X_n^2\ X_nY_n\ Y_n^2 & X_n^3\ X_n^2Y_n\ X_nY_n^2\ Y_n^3 \end{pmatrix}}_{\mathbf{A}} \bullet \underbrace{\begin{pmatrix} a_1\ b_1 \\ \\ a_{10}\ b_{10} \end{pmatrix}}_{\mathbf{x}} = \underbrace{\begin{pmatrix} x_1\ y_1 \\ \\ x_n\ y_n \end{pmatrix}}_{\mathbf{B}} - \underbrace{\begin{pmatrix} u_1\ v_1 \\ \\ u_n\ v_n \end{pmatrix}}_{\mathbf{v}}$$

in matrix notation: $\mathbf{A} \bullet \mathbf{x} = \mathbf{B} - \mathbf{v}$

Number of GCPs

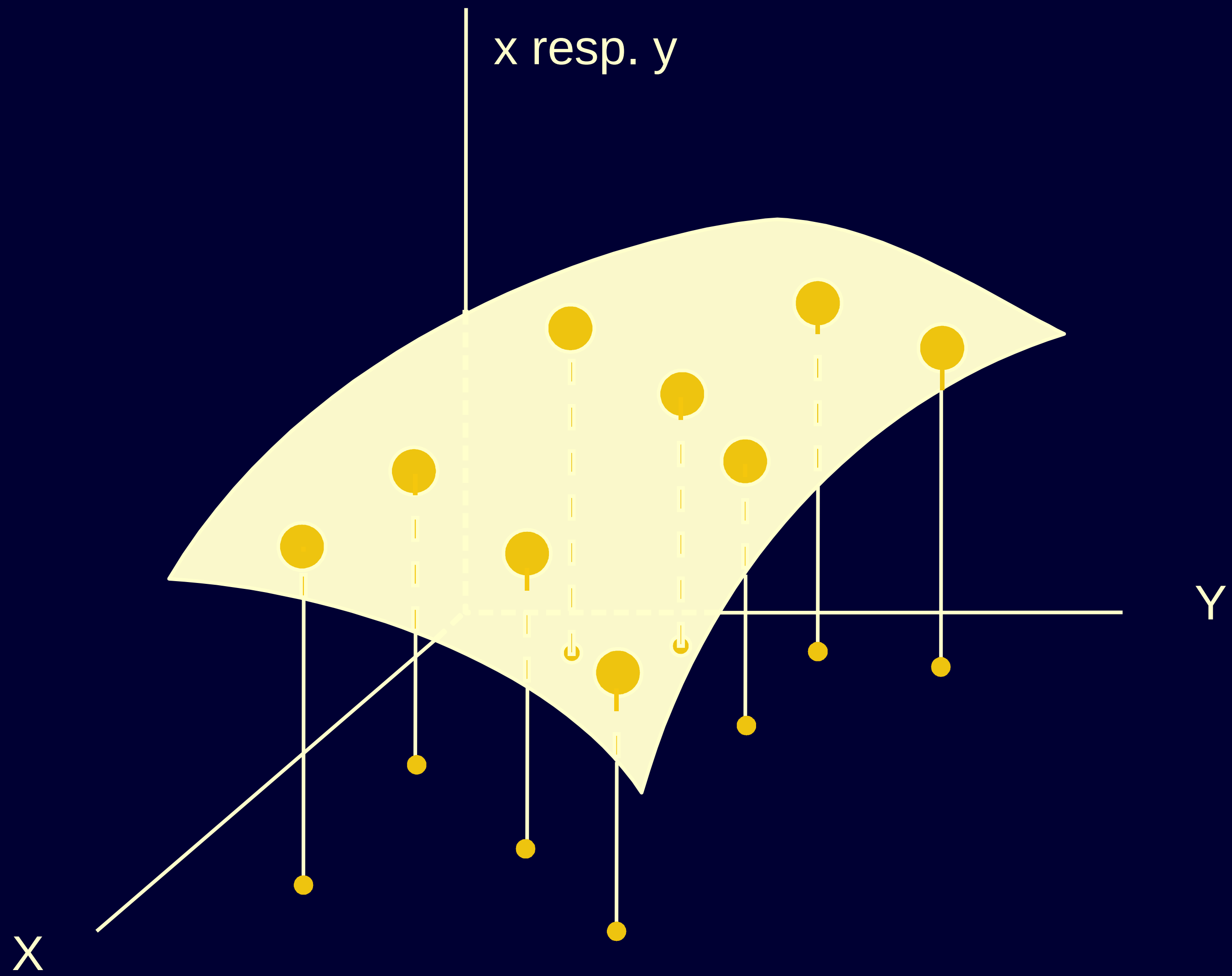
- first order polynomial $\rightarrow$ $n \geq 3$
- second order polynomial $\rightarrow$ $n \geq 6$
- third order polynomial $\rightarrow$ $n \geq 10$

n = number of ground control points

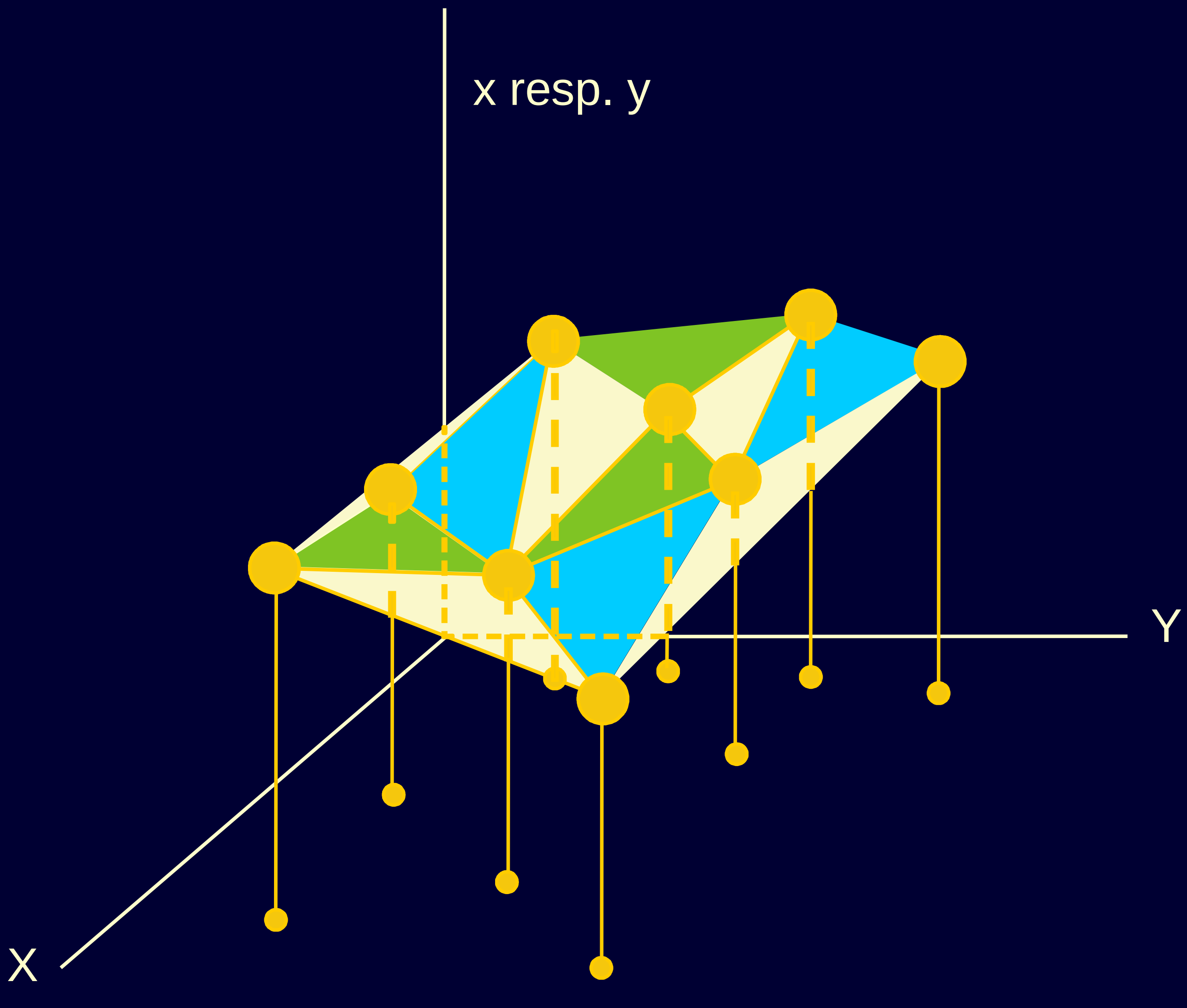
Correction of geometric distortion

Illustration from curve fitting to reinforce the potentially poor behaviour of high order mathematical functions when used to extrapolate

Trend Model



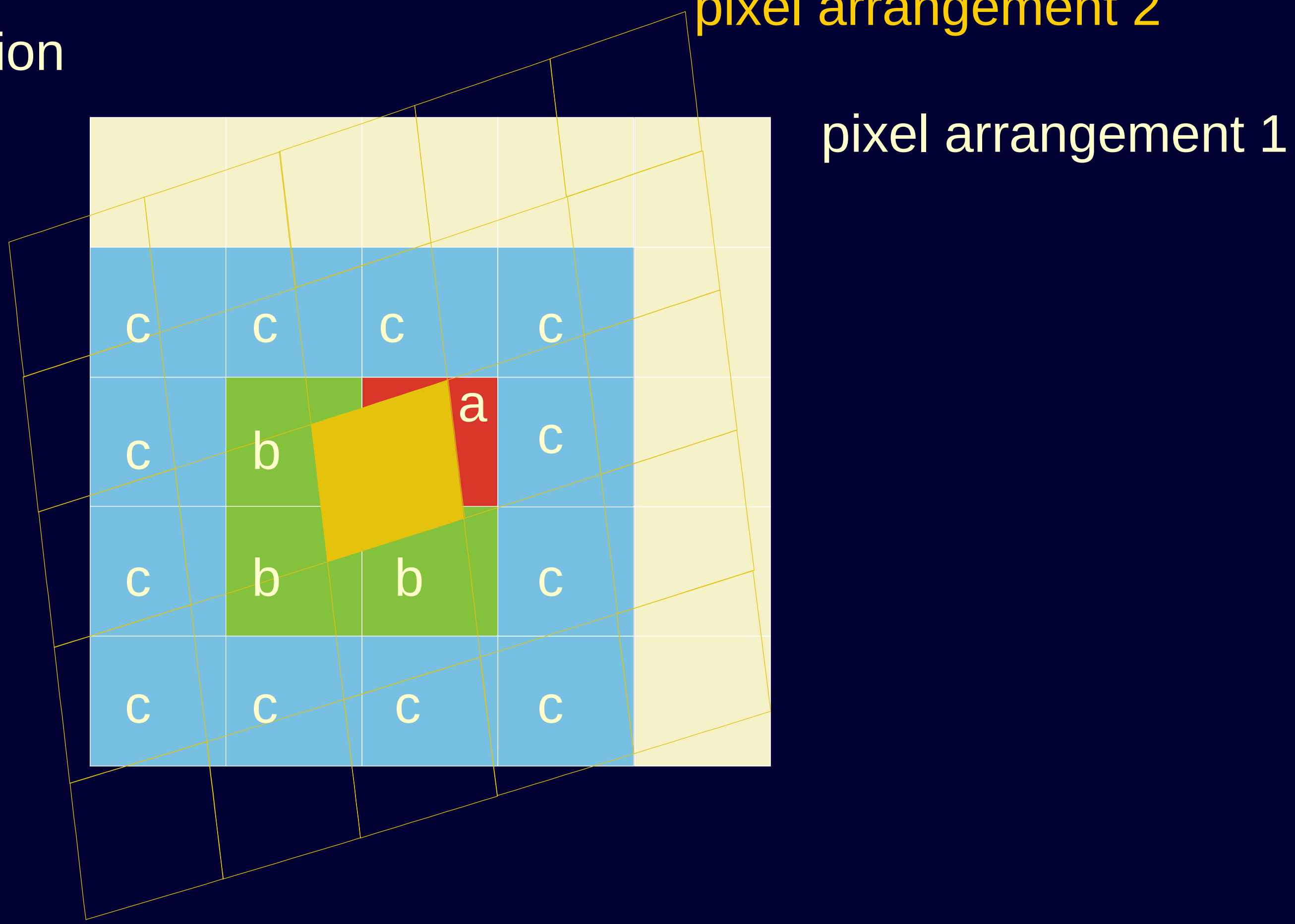
Facet Model



Resampling

After the transformation, a **resampling** of the pixel values is performed

- nearest neighbour
- bilinear interpolation
- cubic convolution



pixel arrangement 1 = input (distorted)
pixel arrangement 2 = output (corrected)

Resampling -2-

Nearest neighbour:

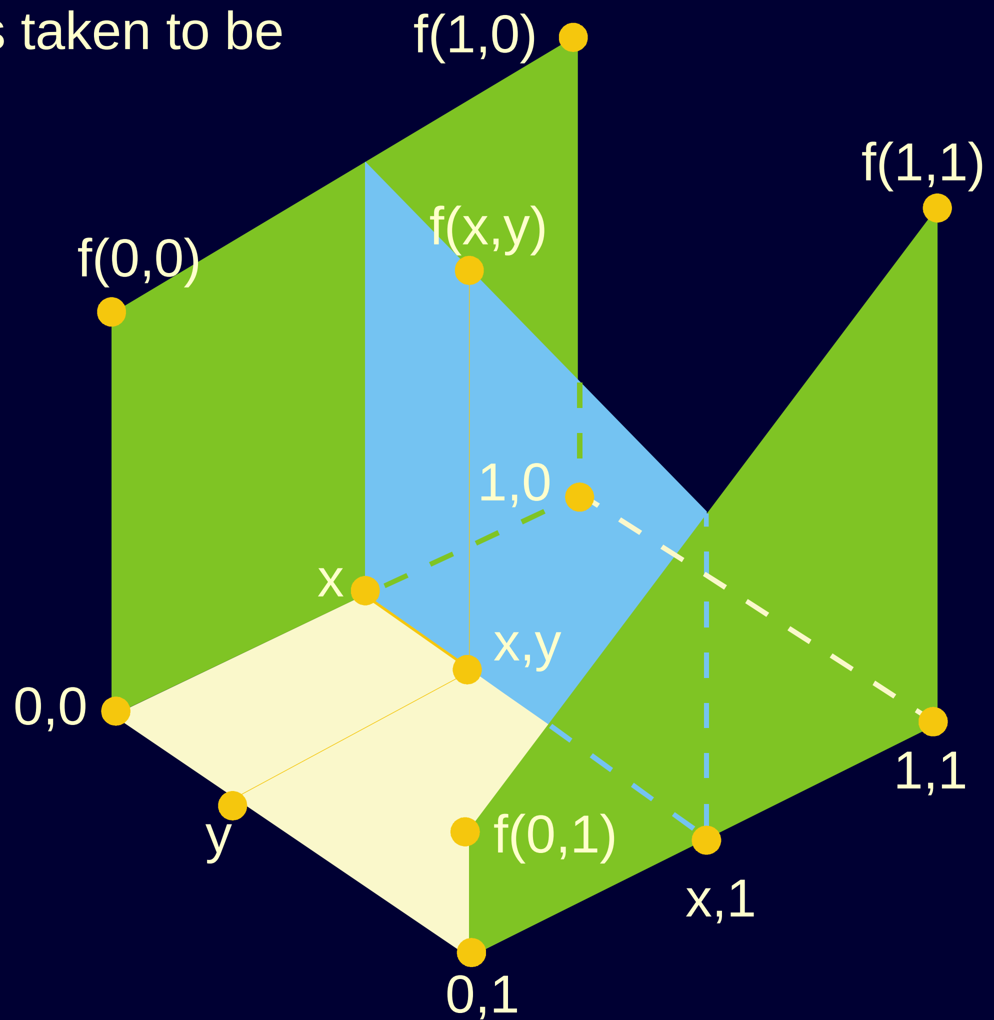
the value of the output pixel is taken to be that of the input pixel nearest to which it maps (a)

Bilinear interpolation:

first-order interpolation between four adjacent input pixels (a and b)

Cubic convolution:

cubic function based on 16 input pixels (a, b and c)



Nearest Neighbour

Advantages:

- extremes and subtleties are not lost
- fast computation

Disadvantage:

- resampling to smaller grid size $\rightarrow$ "stair stepped" effect around diagonal lines and curves

Bilinear Interpolation

Advantages:

- spatially more accurate than nearest neighbour
- results are smoother, without "stair stepped" effect that is possible with nearest neighbour

Disadvantage:

- edges are smoothed and some extremes of the data file values are lost

Cubic Convolution

Advantages:

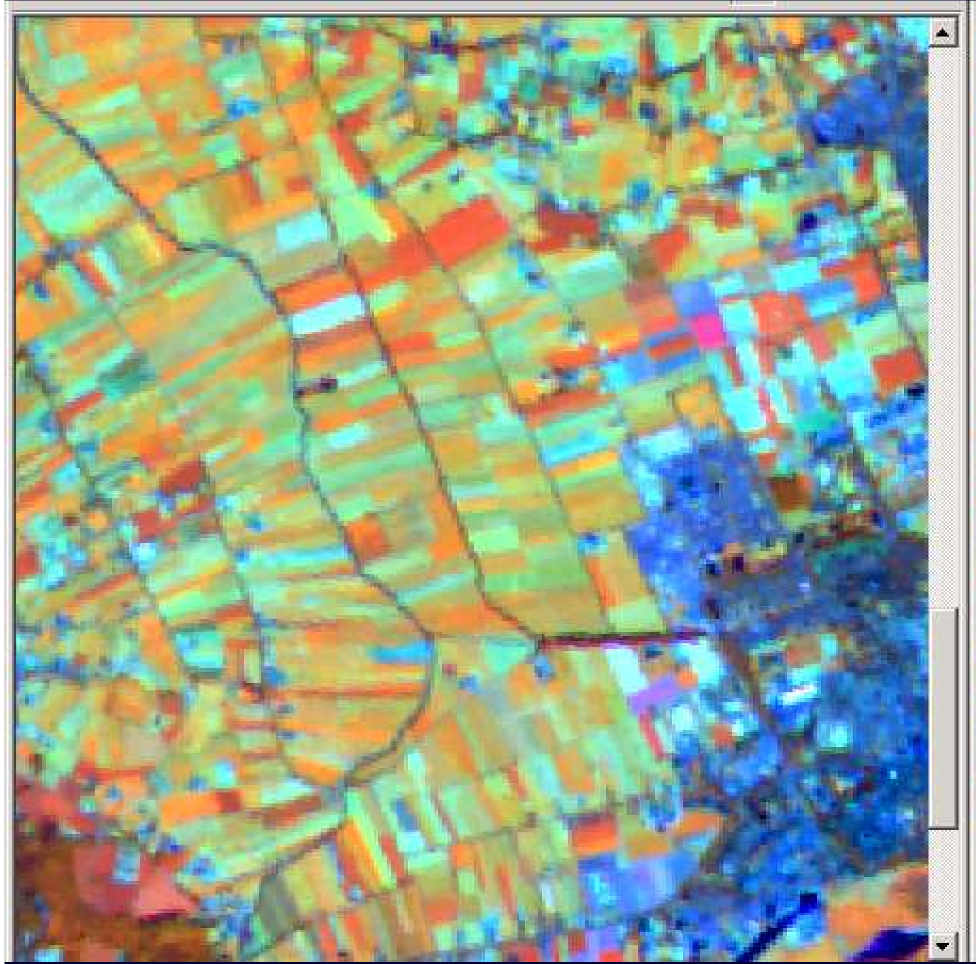
- most accurate resampling method
- effect of cubic curve weighting can both sharpen the image and smooth out noise (effects are data dependent!)

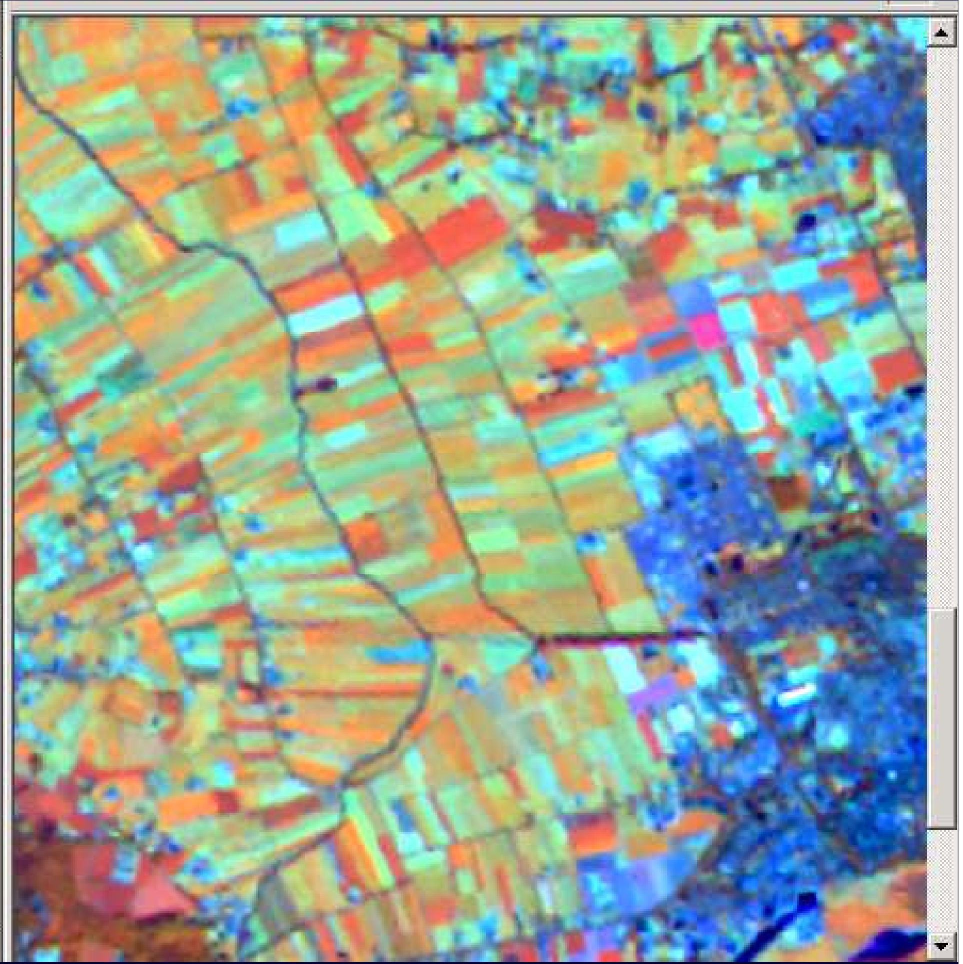
Disadvantages:

- most computational intensive resampling method
- convolution effect may **not** produce the desired results

Resampling

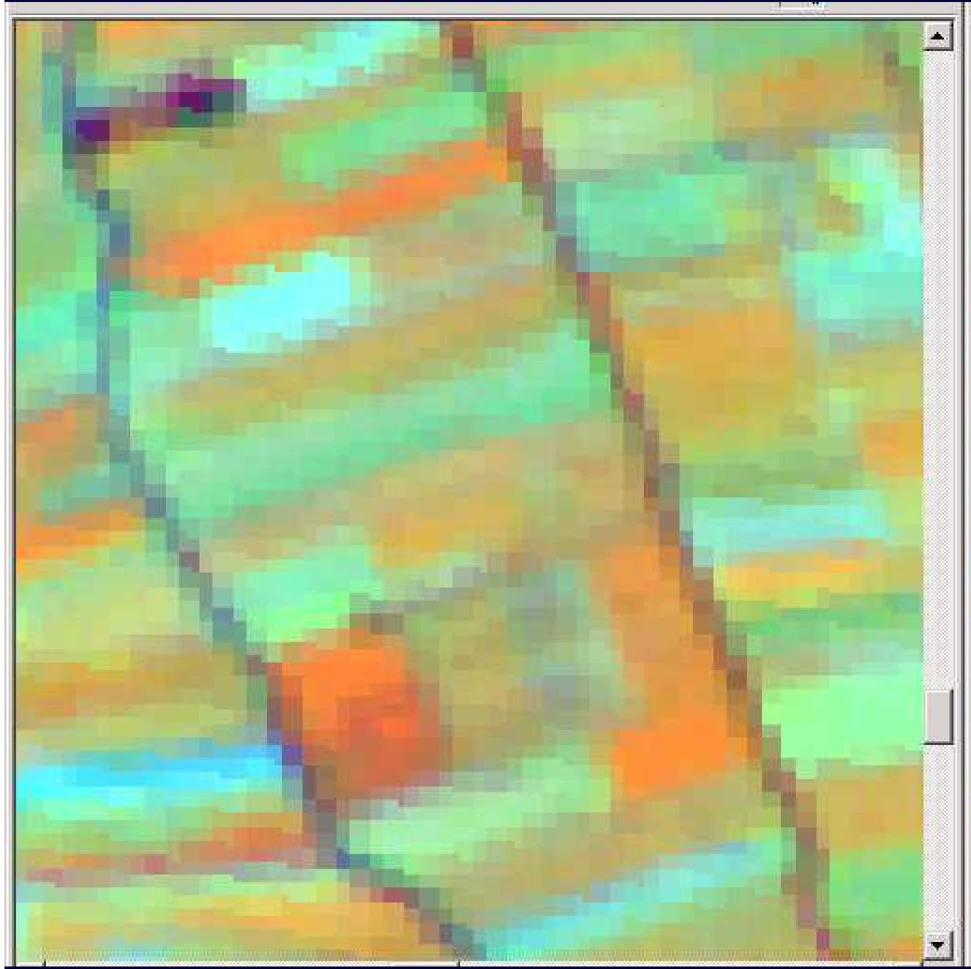
Nearest Neighbour | Cubic Convolution

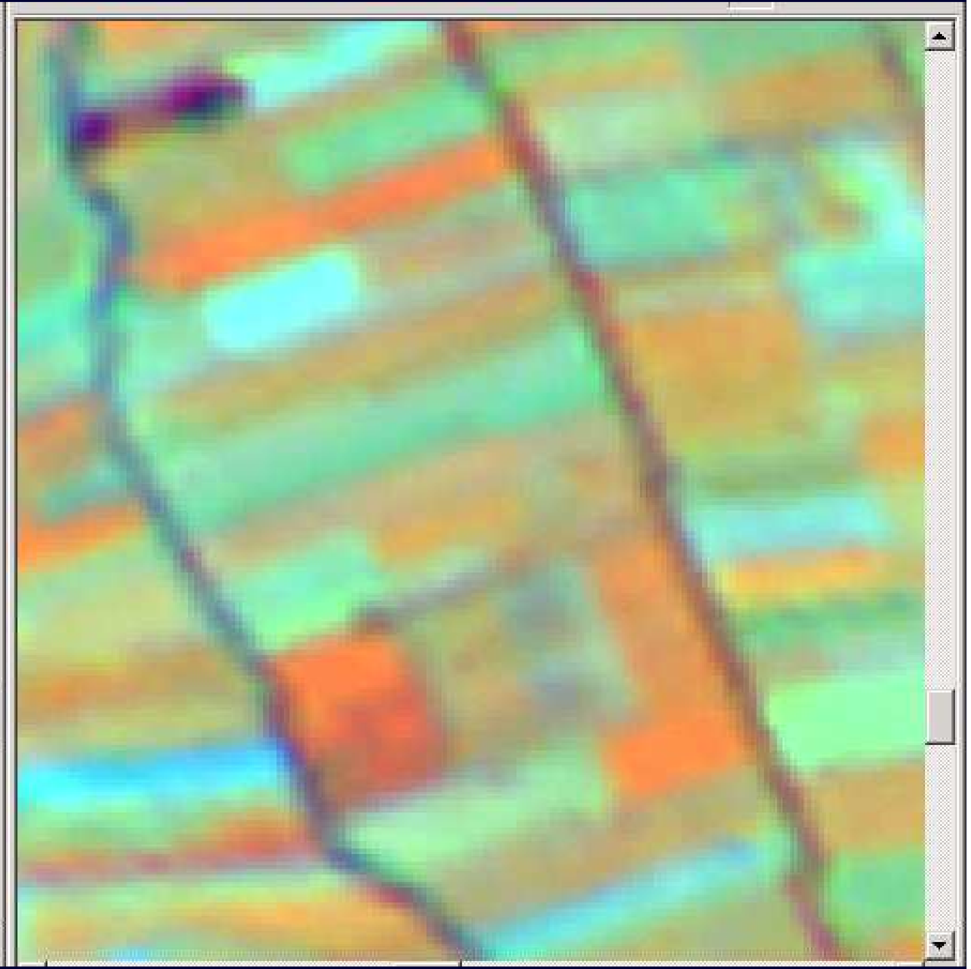




Resampling

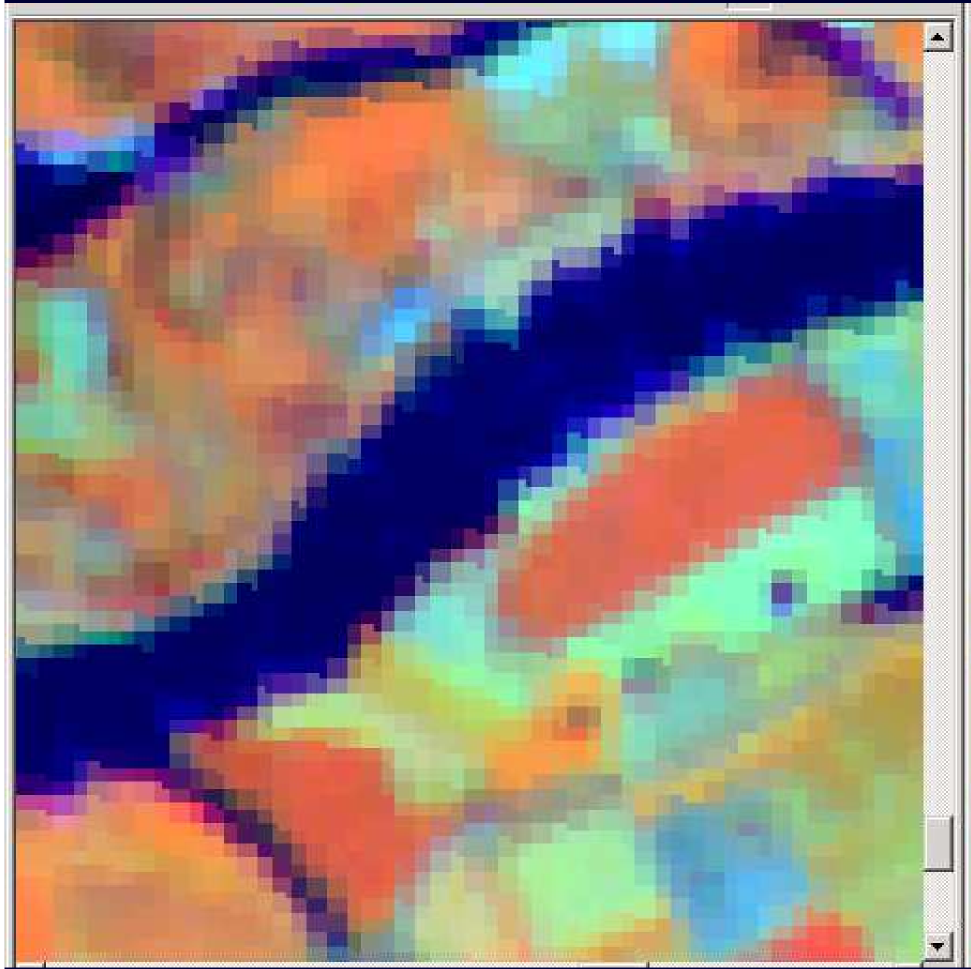
Nearest Neighbour | Cubic Convolution



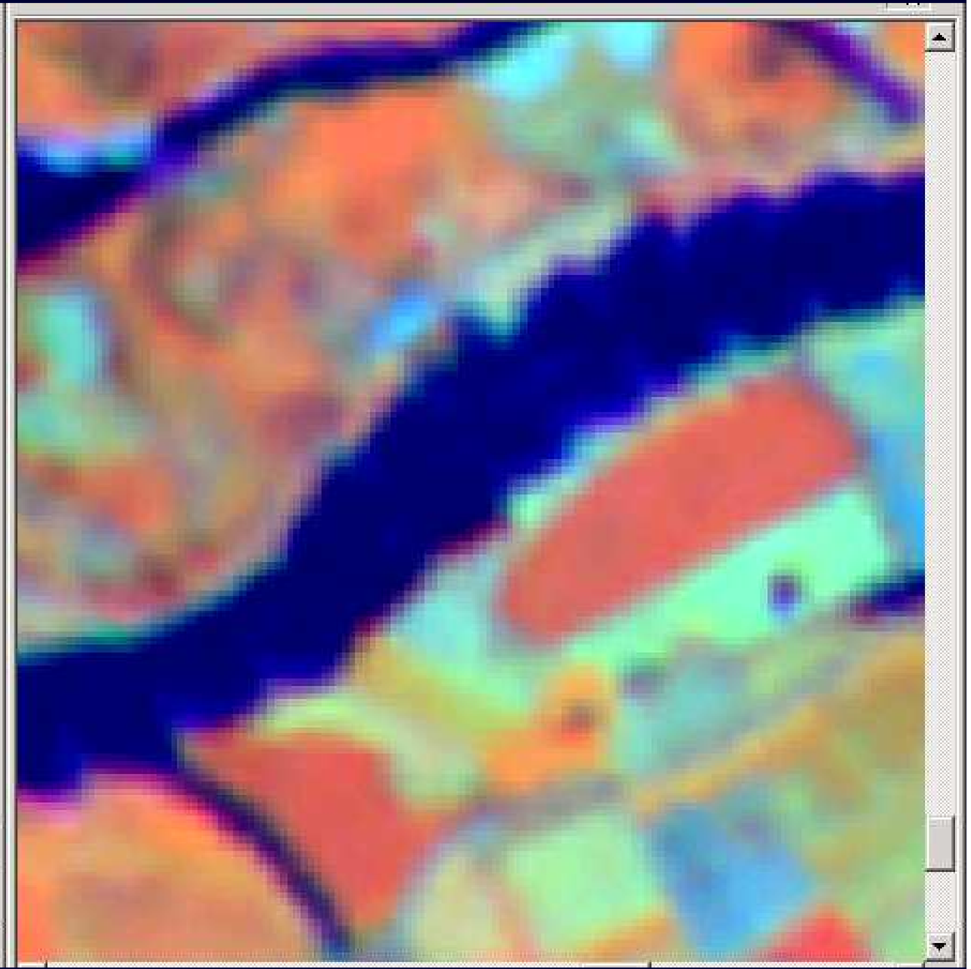


Resampling

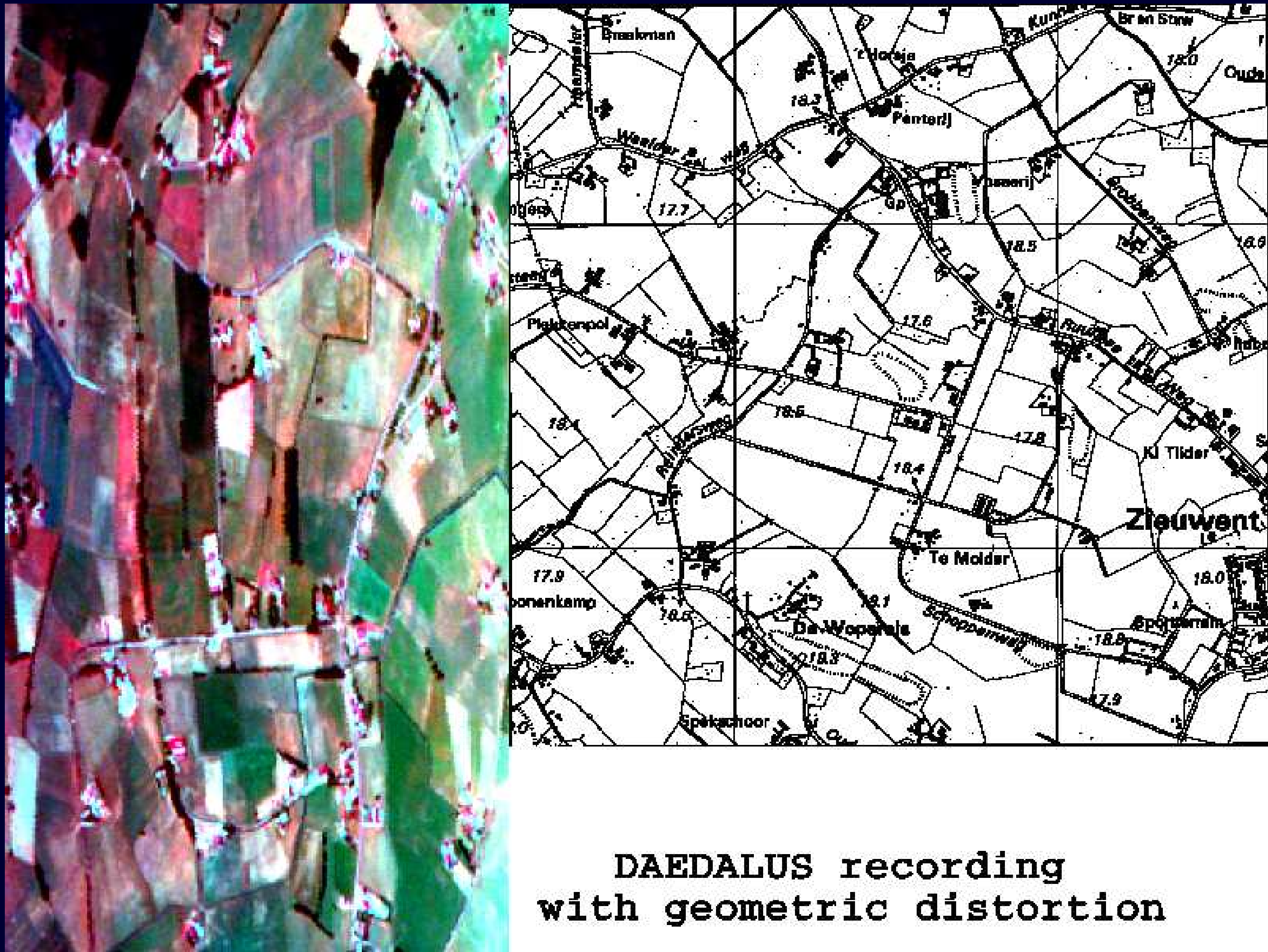
Nearest Neighbour



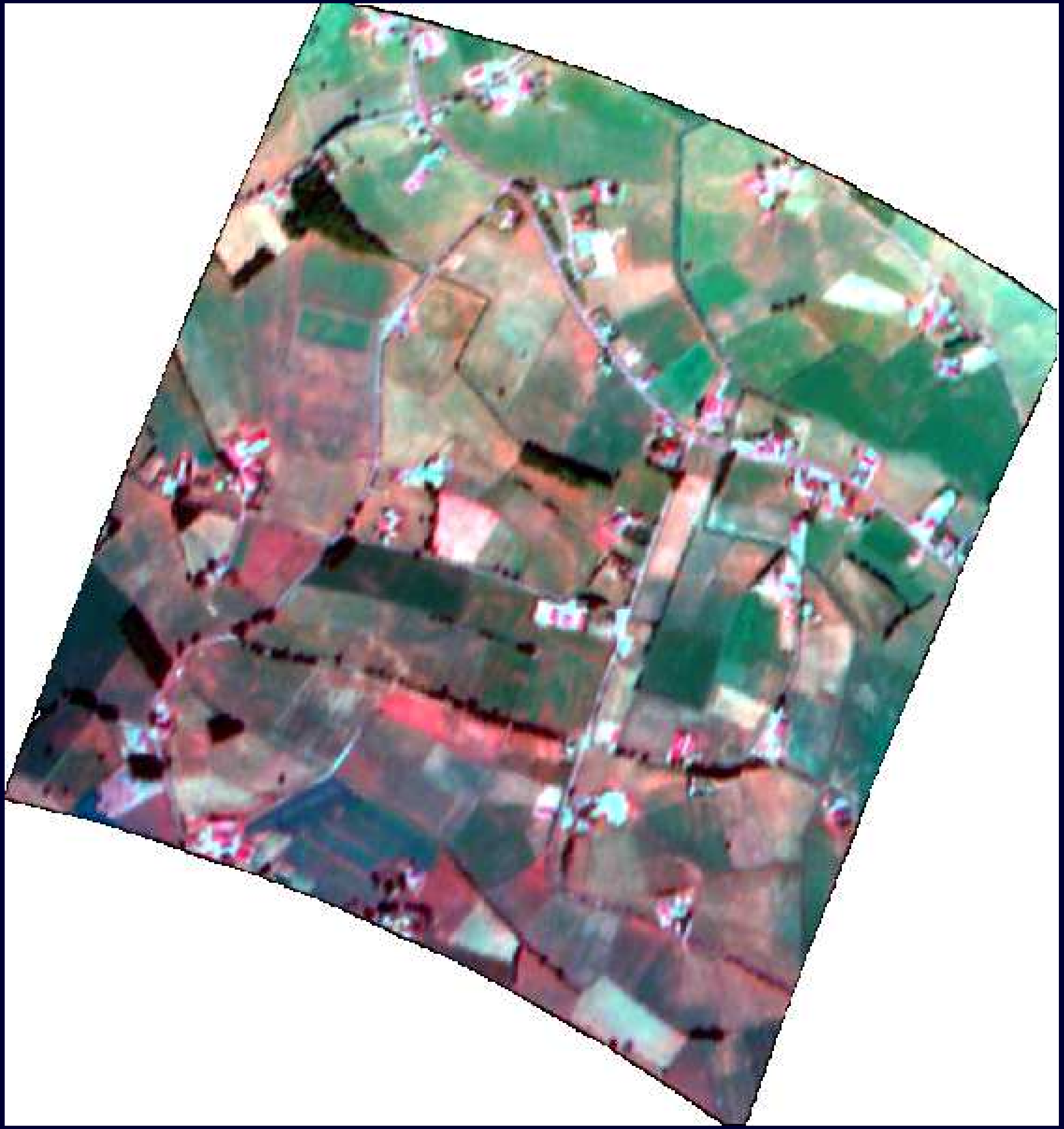
Cubic Convolution



Airborne Daedalus image of Zieuwent



Result of 3rd order transformation



Result with bad distribution of GCPs