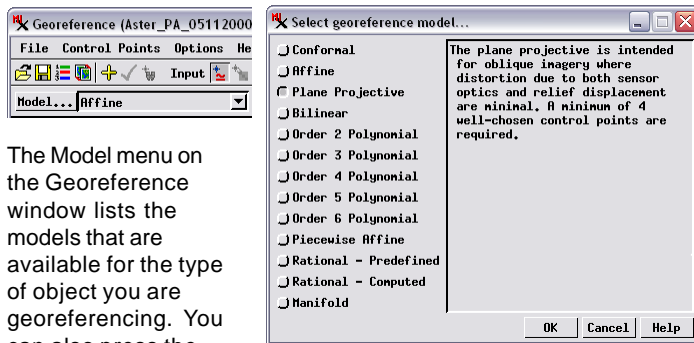# Choosing a Model

In the georeference process you can choose from a number of mathematical models to compute control point residuals and judge the fit of individual points. These models are coordinate transformations that relate the spatial distribution of control points in object coordinates to their distribution in reference (map) coordinates. The available georeference models are described in a table on the next page.

If the object you have selected to georeference does not have an existing georeference subobject, you are automatically prompted to select a model to use initially for georeferencing. The *Select georeference model* window (illustrated below) lists the models that are available for the type of object you are georeferencing. Simpler models requiring fewer control points are shown at the top of the list. This window provides a brief explanation of each model to aid you in selecting one that is appropriate for your spatial object.
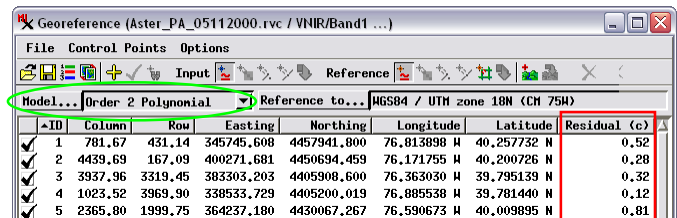

The Model menu on the Georeference window lists the models that are available for the type of object you are georeferencing. You can also press the Model pushbutton to open the the *Select Georeference Model* window, which provides brief descriptions of the available models. This window opens automatically if the object you select to georeference does not have previous georeference information.

For ungeoreferenced objects, the list shown in the initial *Select georeference model* window includes a georeference option for objects that do not require control points: Simple for a raster object and Implied for a geometric object. Use of these options is documented in the Technical Guide entitled *Georeference: Simple and Implied.*

After the initial setup sequence, the current model is shown in the Model menu above the control point list in the Georeference window. You can use this menu to change residual models at any time as you create or edit the control points and note the effect on residual values for individual control points as well as the mean residual values. Your last choice of model is saved with the georeference subobject so that the correct model is set if you reopen the object in the Georeference process. The saved model is also used in the Automatic Resampling and Geometric Warping processes when you use the default selection *From Georeference* from the Model menu in these processes.
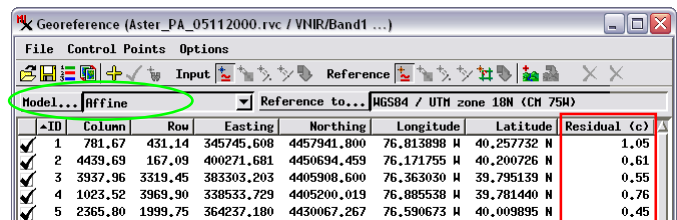
Models of varying mathematical complexity are provided to account for different types of spatial distortion that may be present in the object you are georeferencing. Simpler mathematical models may be used to account for relatively uniform distortion, such as shrinkage of a paper map prior to scanning or tilt distortion in an aerial image acquired at an oblique angle to the ground. More complex models can partially compensate for non-uniform, spatially-varying distortion within an aerial or satellite image such as can be introduced by the optics of an imaging system or by terrain effects (relief displacement; see illustration below). The minimum number of non-colinear control points needed to compute a particular residual model increases with the mathematical complexity of the model, as shown in the table on the next page. You must enter at least one more than the minimum number of points for the current model in order for the Georeference process to automatically determine the best global fit of control point locations (in object and map coordinates) to the model and to compute residuals for individual control points.

A more complex georeference model may account for internal distortion within the spatial object you are georeferencing better than a simpler model. In this example of an ASTER satellite image, the Order 2 Polynomial model (above) provides a better fit (lower control point residual values) than the simple Affine model (below). Only 5 out of 14 control points are shown in these illustrations.

Two rational polynomial model options are available for georeferencing raster images. A rational polynomial model enables orthorectification of the image in the Resample process; it relates row and column coordinates in the unrectified image to latitude and longitude coordinates and terrain elevation. Both rational polynomial options require 3D control points and selection of a reference elevation raster. The Rational - Predefined option is used when rational polynomial coefficients have been provided with the image. The Rational - Computed option is used to compute a rational polynomial expression from the 3D control points. The Auto-Register operation may be used to generate the required 3D control points. For more information see the TechGuide entitled *Georeference: Compute Rational Polynomial Model for Orthorectification.*

(over)

Available Georeference Coordinate Transformation Models

Models Supported	Minimum Non-colinear Points / Description	
Conformal	2	Supports uniform scaling and rotation and thus will not change the object geometry.
Affine	3	Supports separate linear scaling factors in the X and Y directions, as well as rotation and axis shear.
Plane Projective	4	Intended for oblique imagery where distortion due to both sensor optics and relief displacement are minimal.
Bilinear	4	Models lens distortion where not enough control points can be located for higher-order polynomial models.

Polynomials:
   Order 2
   Order 3
   Order 4
   Order 5
   Order 6
	6
	10
	15
	21
	28
		Polynomials may be used to model various types of non-uniform distortion. To ensure mathematical stability it is recommended that at least twice the minimum number of control points be defined.

Piecewise Affine	3	Assumes control points are correctly located in both object and map coordinates; no best fit or residuals are computed. Creates a triangular mesh using the specified control points, with each triangle having its own affine model derived from its vertices. The mesh may be extrapolated to the edges of the object. Individual distorted control point locations only affect the immediately surrounding triangles.
Rational - Predefined (images only)		Uses rational polynomial formula coefficients provided with the image to compensate for image distortions due to sensor orientation and optics as well as topographic effects. Requires 3D control points (with Z values), selection of a DEM raster, and geoid height at the image location.
Rational - Computed (images only)	20	Computes a rational polynomial formula from 3D control points to compensate for image distortions due to sensor orientation and optics as well as topographic effects. Requires 3D control points (with Z values), selection of a DEM raster, and geoid height at the image location. A minimum of 20 well-chosen control points are required, and typically at least 50 are needed for accurate results.
Manifold	3	Allows an image to be projected onto a 3D manifold mesh. The user may specify 3D control points and breaklines. A typical use is to georeference scans of geological cross-sections.