

# About coordinate systems

The features on a map reference the actual locations of the objects they represent in the real world. The positions of objects on the earth's spherical surface are measured in degrees of latitude and longitude, also known as *geographic coordinates*. While latitude and longitude can locate exact positions on the surface of the earth, they are not uniform units of measure; only along the equator does the distance represented by one degree of longitude approximate the distance represented by one degree of latitude. To overcome measurement difficulties, data is often transformed from the three-dimensional geographic coordinate system to the two-dimensional planar surface in a *projected coordinate system*. Projected coordinate systems describe the distance from an origin (0,0) along two separate axes—a horizontal x-axis representing east–west and a vertical y-axis representing north–south.

Because the earth is round and maps are flat, getting information from the curved surface to a flat one involves a mathematical formula called a *map projection*. A map projection transforms latitude and longitude to x,y coordinates in a projected coordinate system.

This process of flattening the earth will cause distortions in one or more of the following spatial properties: distance, area, shape, and direction. No projection can preserve all these properties and, as a result, all flat maps are distorted to some degree. Fortunately, you can choose from many different map projections. Each is distinguished by its suitability for representing a particular portion and amount of the earth's surface and by its ability to preserve distance, area, shape, or direction. Some map projections minimize distortion in one property at the expense of another, while others strive to balance the overall distortion. As a mapmaker, you can decide which properties are most important and choose a projection that suits your needs.

## Do you need to display your data with a projected coordinate system?

If your spatial data references locations with latitude and longitude—for example, decimal degrees—you can still display it on your map. ArcMap draws the data by simply treating the latitude–longitude coordinates as planar x,y coordinates. If your map doesn't require a high level of locational accuracy—if you won't be performing queries based on location and distance or if you just want to make a quick map—you might decide not to transform your data to a projected coordinate system.

If, however, you need to make precise measurements on your map, you should choose a projected coordinate system. When displaying and performing analysis with datasets, they should be in the same coordinate space and in the same projection. If two datasets are in different coordinate systems, the values of the coordinates are on different scales. Errors will occur when comparing such datasets because they will represent different locations.

## Reasons for using a projected coordinate system

- You want to make accurate measurements from your map and be sure that spatial analysis options you use in ArcMap calculate distance correctly. Latitude–Longitude is a good system for storing spatial data but not very good for viewing, querying, or analyzing maps. Degrees of latitude and longitude are not consistent units of measure for area, shape, distance, and direction.
- You are making a map in which you want to preserve one or more of these properties: area, shape, distance, and direction.
- You are making a small-scale map such as a national or world map. With a small-scale map, your choice of map projection

determines the overall appearance of the map. For example, with some projections, lines of latitude and longitude will appear curved; with others they will appear straight.

- Your organization mandates using a particular projected coordinate system for all maps.

### What is an on-the-fly projection?

ArcMap can perform what is commonly known as an on-the-fly projection. This means ArcMap can display data stored in one projection as if it were in another projection. The new pseudoprojection is for display and query purposes only. The actual data is not altered. Data is projected on the fly anytime a dataframe contains a layer whose coordinate system is defined as something different from the coordinate system definition of the dataframe. A dataframe's coordinate system can be defined by adding data with a defined coordinate system or by manually setting the coordinate system (by accessing the dataframe's properties).

ArcMap will not project data on the fly if the coordinate system for the dataset has not been defined. A dataset with an undefined coordinate system will simply be displayed in its native coordinate system. The coordinate system for any dataset can be defined using ArcCatalog.

The first layer added to the dataframe defines its coordinate system. This is true whether the data is projected or geographic. For example, if the first layer added contains a Lambert Conformal Conic projected coordinate system, all other layers will project on the fly to match this. Similarly, if the first layer added to the dataframe contains data that uses a WGS84 geographic coordinate system, all other layers will adjust to match this. Even data that uses a projected coordinate system will unproject on the fly.

For information on projecting rasters on the fly, see Chapter 9, 'Working with rasters'.

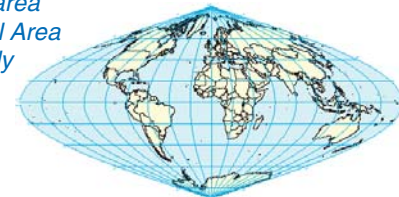
### What type of map projection should you choose?

Here are a few things to consider when choosing a projection:

- Which spatial properties do you want to preserve?
- Where is the area you're mapping? Is your data in a polar region? An equatorial region?
- What shape is the area you're mapping? Is it square? Is it wider in the east–west direction?
- How big is the area you're mapping? On large-scale maps, such as street maps, distortion may be negligible because your map covers only a small part of the earth's surface. On small-scale maps, where a small distance on the map represents a considerable distance on the earth, distortion may have a bigger impact, especially if you use your map to compare or measure shape, area, or distance.

Answering these questions will determine which map projection and thus which projected coordinate system you'll want to use to display your data.

*Equal area projections preserve area and are also called equivalent projections. Most thematic maps should use an equal area projection. The Albers Equal Area Conic projection is commonly used for the United States; common projections for the world are Equal Area Cylindrical and Sinusoidal.*



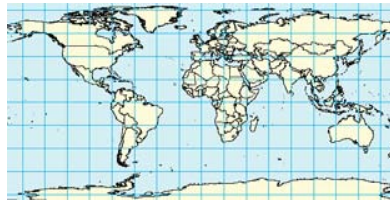
Map projections can generally be classified according to which spatial attribute they preserve (distance, area, shape, or direction).

Conformal projections preserve angles and are useful for navigational charts and weather maps. Shape is preserved for small areas, but the shape of a large area, such as a continent, will be significantly distorted. Common conformal projections are the Lambert Conformal Conic and the Mercator.



Azimuthal projections preserve direction from one point to all other points. This property can be combined with preserving either area, angles, or distance. Thus, it is possible to have an Equal Area Azimuthal projection, such as Lambert, or an Equidistant Azimuthal projection.

Equidistant projections preserve distances, but no projection can preserve distances from all points to all other points. Instead, distance can be held true from one point (or a few points) to all other points or along all meridians or parallels. If you will be using your map to find features that are within a certain distance of other features, you should use an equidistant map projection.



Compromise projections minimize overall distortion but preserve none of the four properties. The Robinson projection, for example, is neither equal area nor conformal but is aesthetically pleasing and useful for general mapping.

For more information on coordinate systems, see *Understanding Map Projections*.

## Specifying a coordinate system

If all the data you want to display on your map is stored in the same coordinate system—for example, you’re using your organization’s database—you can just add it to a map and not consider whether the layers will overlay properly; they will. If, however, you’ve collected data from a variety of sources, you’ll need to know what coordinate system each dataset uses to ensure ArcMap can display them together.

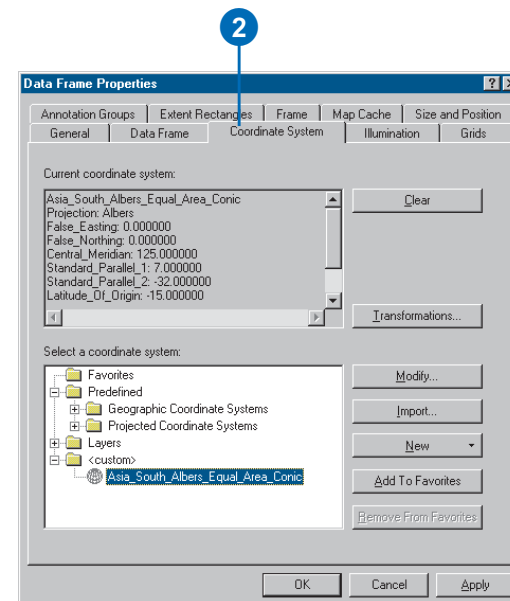
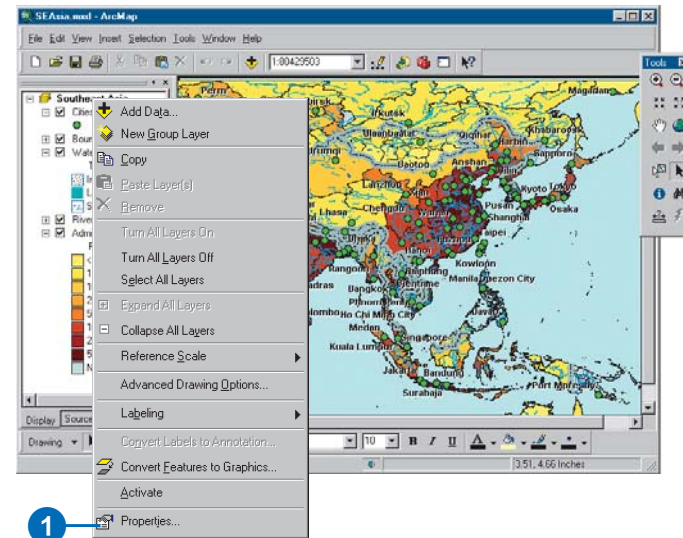
When you add a layer to an empty dataframe, that layer sets the coordinate system for the dataframe; you can change it later if necessary. As you add subsequent layers, they are automatically transformed to the dataframe’s coordinate system as long as there’s enough information associated with the layer’s data source to determine its current coordinate system. If there isn’t enough information, ArcMap will be unable to align the data and display it correctly. In this case, you’ll have to supply the necessary coordinate system information yourself.

ArcMap expects coordinate system information to be stored with the data source. For each ►

## Finding out which coordinate system your data is currently displayed with

1. Right-click the dataframe that you want to determine the coordinate system of and click Properties.
2. Click the Coordinate System tab.

The details of the current dataframe coordinate system display in the dialog box.



layer in a geodatabase, this information is part of the layer's metadata. For coverages, shapefiles, and rasters, it's stored on disk in a separate file named after the data source but with a .prj file extension—for example, streets.prj. These files are optional files; thus you may still need to define the coordinate system for one of these data sources. You can create a .prj file with ArcCatalog.

If no coordinate system information is associated with a data source, ArcMap will examine the coordinate values to see if they fall within the range: -180 to 180 for x-values and -90 to 90 for y-values. If they do, ArcMap assumes that these are geographic coordinates of latitude and longitude. If the values are not in this range, ArcMap simply treats the values as planar x,y coordinates.

### Tip

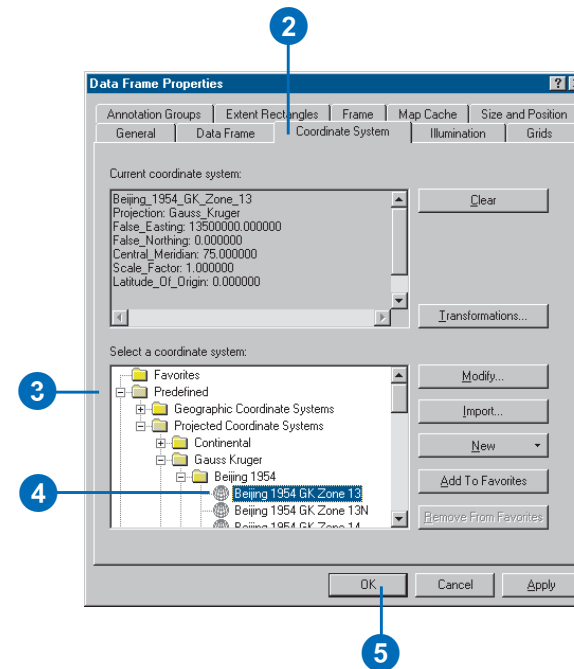
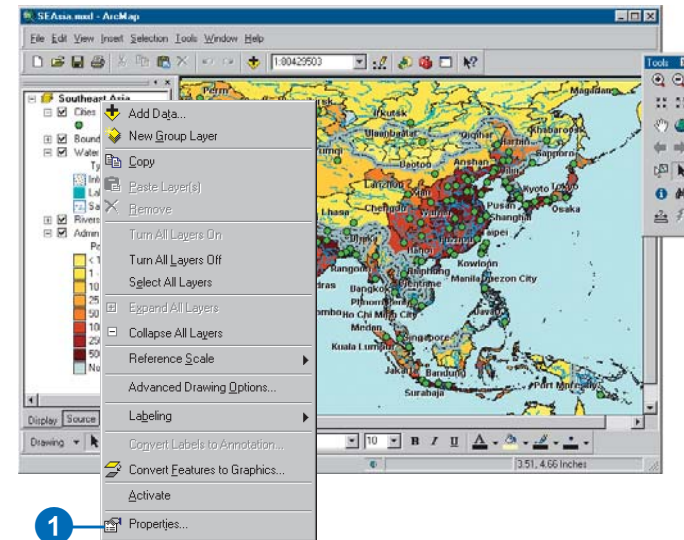
#### Changing the coordinate system of a dataframe

*Changing the coordinate system of a dataframe does not alter the coordinate system of the source data contained in it.*

## Displaying data with a predefined coordinate system

1. Right-click the dataframe that you want to set the coordinate system of and click Properties.
2. Click the Coordinate System tab.
3. Double-click Predefined.
4. Navigate through the folders until you find the coordinate system you want and click it.
5. Click OK.

All layers in the dataframe will now be displayed with that coordinate system.

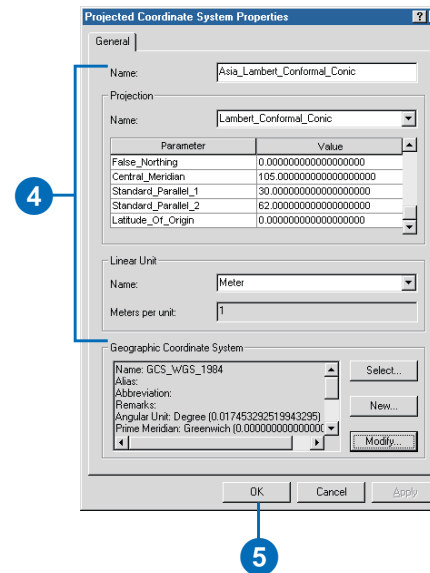
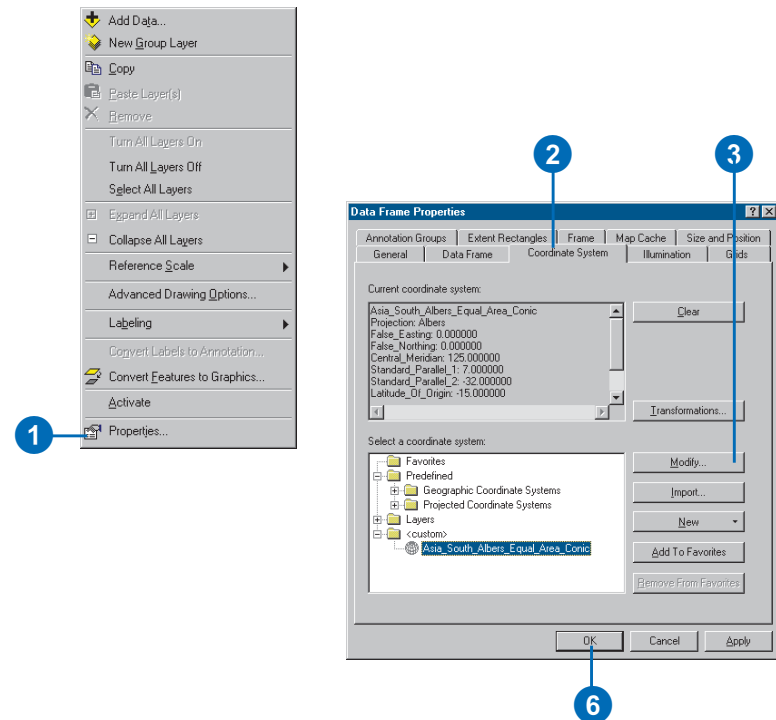


## See Also

For more information on coordinate systems, see Understanding Map Projections.

## Modifying the parameters of a coordinate system

1. Right-click the dataframe whose coordinate system you want to modify and click Properties.
2. Click the Coordinate System tab.
3. Click Modify.
4. Adjust the coordinate system properties as appropriate.
5. Click OK.
6. Click OK on the Data Frame Properties dialog box.



## Tip

### Do you want to see meters, miles, or feet?

When you measure lengths or find places by their coordinates, you can choose which units you want to use. Set the Display Units property as needed.

## Tip

### Why can't I set the map units?

Map units are a property of the coordinate system defined with your data. You can change the map units by modifying the coordinate system. Right-click the dataframe containing your data and click the Coordinate System tab. Here you can modify the parameters of the coordinate system.

## Setting the units for reporting lengths and displaying coordinates

1. Right-click the dataframe and click Properties.
2. Click the General tab.
3. Click the Map dropdown arrow and click the appropriate units.

The map units option is only available when your data has no coordinate system information associated with it.

4. Click the Display dropdown arrow and click the appropriate units.
5. Click OK.

