

REMOTE SENSING FOR NATURAL HAZARD STUDIES

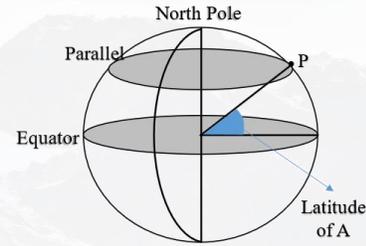
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Lec 11b: Introduction to Geographical Information System for Data Analysis-Part B

Hello everyone, welcome back to Lecture 11. This is part 2 of Lecture 11. So, we will continue the discussion on Geographic Information Systems for Data Analysis. So, you can see this particular map and tell me whether you feel that this is a good representation of Earth. Forget about these boundaries, so these boundaries are not correct. So, for any country, this boundary is not correct, but whether you see that this map is a good representation or a good way of representation. So, you see this particular map; what do you feel? Whether the previous one was better or this one is better. So, here you will obviously say that this is a better representation of Earth, where the boundaries are properly mapped, and all these positions, the value of the latitude and longitude, can be identified because you have the location values. So, this is the best way to represent our Earth. So, when we have the latitude, longitude, or location information, that is the best way to represent our Earth. Can we use a reference system to identify the location of a place? Now, how did you arrive at this value, whether 60 should be here or here, how do you know whether we have a reference system or whether we are following a standard protocol by which we are generating the location value for any given position on this particular map? So, we started with Earth as a sphere. So, initially, we started looking at the Earth, considering it is a sphere. So, we started with a spherical earth model that represents the shape of the earth with a sphere of a specified radius. Here, you see you have the North Pole, the South Pole, the Equator, and this is a circle, so this is a sphere. Spherical Earth models are often used for navigation and for global distance approximation. When we started working on the models, Earth models, we started with a spherical Earth model, and this was very early days. So, at that time, it was used for navigation and global distance approximation to determine whether a country is far from its neighboring country, how far it is, and how you are going to navigate through the sea. So, using this spherical model, the job that was done may be used for a coarse-scale map, then we started looking at Earth as an ellipsoid. So, we have started working on the ellipsoidal Earth model.

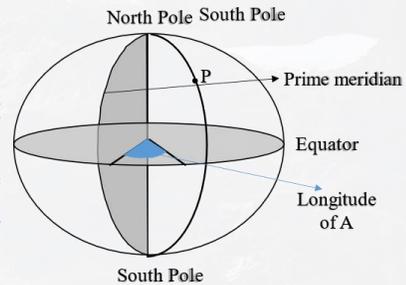
Spherical Earth Models:

- Represent the shape of the earth with a sphere of a specified radius.
- Spherical earth models are often used for navigation and for global distance approximations.
- May be used for coarse-scale maps 1:5,000,000.



Ellipsoidal Earth Models:

- Required for accurate range and bearing calculations over long distances.
- Radio and GPS navigation receivers use the ellipsoidal earth models to compute position and waypoint information.



So, here once you have the ellipsoid, what will happen is that you will have the semi-major and semi-minor axes. So, it requires accurate range and bearing calculation over long distances. Radio and GPS navigation receivers use the ellipsoidal Earth model to compute position and waypoint information accurately. So, here you have the green prime meridian, the equator, then the North Pole, the South Pole, and this is how we were representing the Earth. The ellipsoid is a 3D figure obtained by directional scaling or affine transformation of a sphere. How you are changing a circle to an ellipsoid basically involves compression, so you are trying to apply some extra forces here, and you are changing the shape of the circle to an ellipsoid or a spheroid to an ellipsoid. So, basically, we try to see how it is different from a circle and how it is changing from being a circle. So, the best way these models can represent the shape of the earth over the smooth and average sea surface is to within about 100 meters.

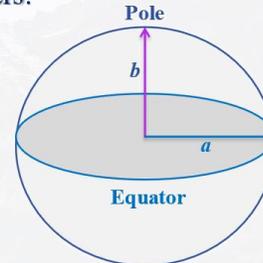
- Ellipsoid is a 3-D figure obtained by directional scaling or affine transformation of a sphere.
- The best of these models can represent the shape of the Earth over the smoothed, averaged sea-surface to within about one hundred meters.
- Flattening (f) is a measure of the compression of a sphere along a diameter to form an ellipsoid, and Eccentricity (e) is a measure of how much the conic section deviates from being circular.

$$\text{Flattening } (f) = (a-b)/a$$

$$\text{WGS84 value} = 1/298.257223563$$

$$\text{Eccentricity square } (e^2) = 2f-f^2$$

$$\text{WGS84 value} = 0.00669427999013$$



Semi-Minor Axis=Polar Radius= b
(WGS84 Value= 6356752.3142 meters)
Semi-Major Axis=Equatorial Radius= a
(WGS84 Value= 6378137.0 meters)

So, here you have an ellipsoid, and the poles and equators are marked, and then you have the semi-minor and semi-major axes. So, this is the polar radius; this is the equatorial radius.

Now, this flattening (f) is very, very important as a measure of the compression of a sphere along a diameter to form an ellipsoid, and the eccentricity (e) is a measure of how much the conic section deviates from being circular. So, we calculate the flattening and the eccentricity correctly. So, this is very simple to understand: how we started. We started with a spheroid, then we considered Earth as an ellipsoid because this is a more appropriate representation of our Earth's surface. To understand this ellipsoidal Earth model, let us examine this particular diagram very carefully. So, this green color is basically the ellipsoid. So, this represents the best representation of our Earth's surface. Where it also matches with the sea surface, it does not matching very well with the topography when there is a hill; that particular location is not matching. So, the actual surface is here, but the ellipsoid is going from here because our Earth is not a smooth surface. However, we can represent our Earth with an ellipsoid, but these surfaces are not matching with each other. So, this is the topography, and here is the difference in height. So, this is the ellipsoid surface; this is the actual surface. So, here A and B are marked, and this is the geocenter of the Earth.

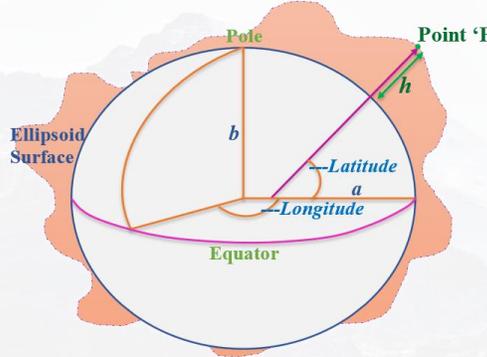
So, the reference ellipsoids are defined by their semi-major and semi-minor axes. Now, let us see a section; this is the whole earth, but now we will see a section. Now, we understand that the global ellipsoid is not a good way to represent our Earth. So, what we will do is go for a local ellipsoid. So, here you can see this is the local ellipsoid that represents this particular area in the best way; just look carefully.

So, here is the topography; this is the ellipsoidal earth surface, and once we have this, it represents the best way, or it represents this particular elevation. So, the local ellipsoids are the best fit for a specific country or region. So, in this particular case, the global ellipsoid was not able to represent this elevation and topography, but if we had an ellipsoid here that may represent a specific country or region. So then, the geoid comes.

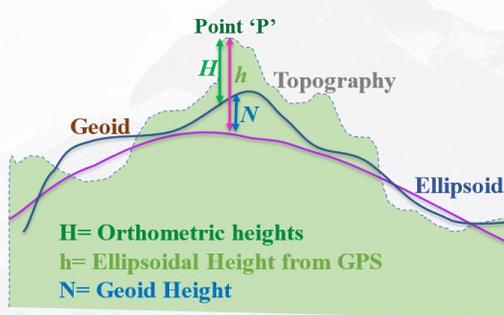
Geoid



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Ellipsoid Surface



H= Orthometric heights
h= Ellipsoidal Height from GPS
N= Geoid Height

Orthometric heights (H) = h - N

Geodetic height is the height of a point on the physical surface of the earth above or below the ellipsoid, measured along a line that passes through the point on the earth and is normal to the surface of the ellipsoid.

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So, it is the equipotential surface of Earth's gravitational field that would coincide with the ocean surface if the Earth were undisturbed and without topography.

The geoid model attempts to represent the surface of the entire Earth over both land and ocean as the surface resulting from gravity alone. So, here, if we forget about the topography, the elevation, and the depression, we only consider the gravitational forces. So, if we consider that, then the surface will match with the ocean surfaces. So, here in the geoid, we consider the gravitational field, and we try to put it into the equipotential surface. So, here is the topography; these dotted lines represent the topography. This is your ellipsoid, which we discussed in the previous slide. Now we have the geoid. So, the geoid is the equipotential surface of the Earth's gravitational field. So, here it is not matching very well with the topography; it does not match very well with the ellipsoid, but we can say that this particular geoid represents the topography in a better manner compared to this ellipsoid.

So, considering this elevation of the actual topography, let us say that point 'P' is present here; then you have the semi-major and semi-minor axes, you have poles here, and the equator is marked here. Now you can see this particular point, the 'P', and this is the ellipsoidal surface.

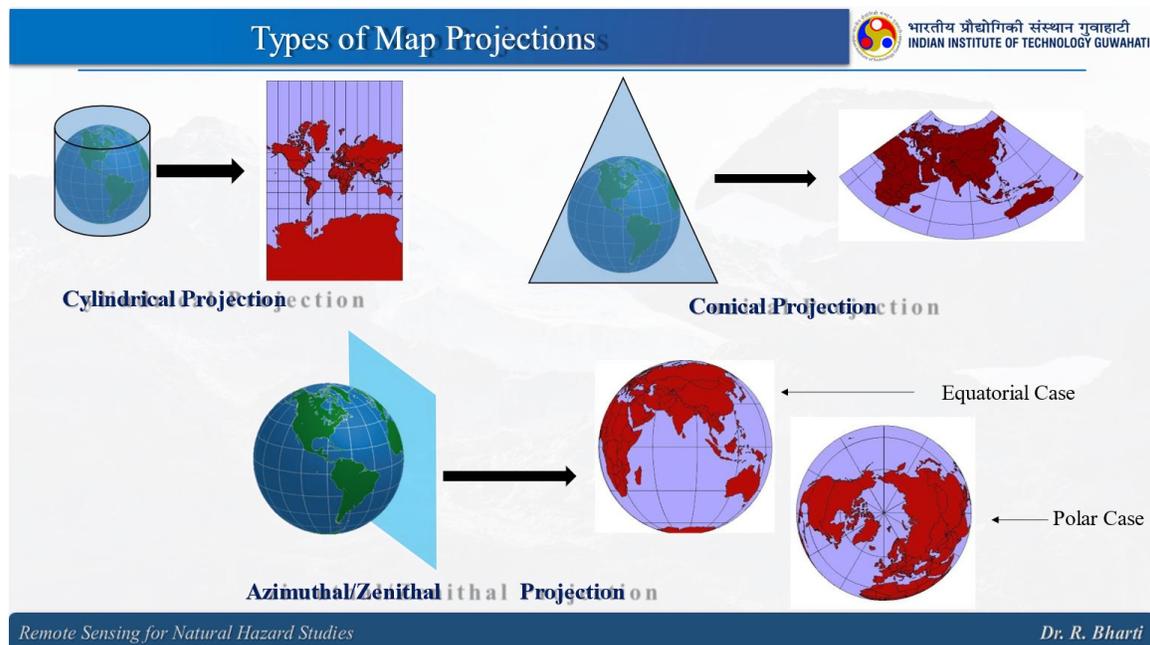
So, you can see the ellipsoidal surface marked here, and this is the actual topography. Then we can just see a section of it. Here in this case, the point 'P' is marked, which is then the actual topography. So, this point we are trying to represent with this actual topography, and here, this is the ellipsoid surface. So, there is a difference between this ellipsoid surface and the actual surface. So, none of them is very close. So, it is very far away. So, it will be very clear once we see that section of it. So, here you have the topography, this is the ellipsoid, this is point 'P', and this is the height difference between the ellipsoid and the topography. So, this is represented by a small h . Now we are trying to place the geoid here.

So, this geoid will be the best representation of the topography. So here you can see that earlier we had this point here, and the difference between the ellipsoid and the topography is represented with small 'h', while the difference between the geoid and the actual topography is represented with capital 'H'. So, we have different terms here; very carefully, you see capital 'H' is the orthometric height, small 'h' is the ellipsoidal height from GPS, and capital 'N' is the difference between the geoid and the ellipsoid, which is the geoid height. So, geodetic height is the height of a point on the physical surface of the Earth above or below the ellipsoid, measured along a line that passes through the point on the Earth and is normal to the surface of the ellipsoid. So, now here you see this 'H', which is the orthometric height. So, this is very, very important. We are going to represent our height with orthometric height. So, this 'H' will be calculated using this expression: $h - n$. So, these two will be used, and then we will calculate the orthometric height. I hope this concept is clear. Now, we will continue this with a map projection. So, what is the basis for having all these values? How do we decide whether it will be latitude or longitude, and what value will be there? So, how we represent a particular surface on a map will be decided based on the map projection.

So, a map projection is a mathematical formula for representing the curved surface of the Earth on a flat map. No flat representation of the Earth can be completely accurate. So, different projections have been developed, not suited for a particular purpose. Now you remember the local and global ellipsoid. So, for a particular small area or for local reasons, the local ellipsoids are better, but if you are going for a larger scale, then global ellipsoids will be better. So, similarly map projection is also developed keeping different objectives in mind. That, if you are going for a small area, if it is near the equator, if it is near the pole, which projection system will represent these areas in a better way? Map projections differ in the way they handle area, shape, distance, and direction. No projection can preserve all of these properties. So, this area, shape, distance, and direction are the key elements, and none of them are able to preserve all these parameters. So, depending on your objective, if you are more worried about the direction, then you have to select a projection system accordingly. So, this is to explain how exactly we are transferring these 3D surfaces onto the 2D map. So, just place plain paper or a tracing

sheet on the globe, and then from here, you just try to use a torch. So, what will happen is all these lines will be projected here on this tracing sheet, and then you trace them on this piece of paper. So, this is how we are representing our 3D surfaces, and depending on the position of this paper, it will represent the area in a better manner. The systematic transformation of the features of the Earth's surface on a 2D map is approximated by an ellipsoid or a sphere, depending on which one you are using. Transform a set of ellipsoidal geographic coordinates representing position on the reference surfaces of the Earth to a set of Cartesian coordinates representing position on the two-dimensional surface of the map correctly.

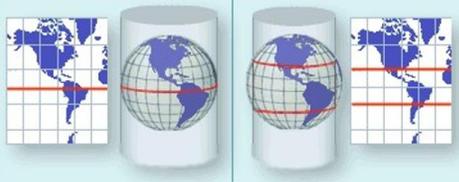
So, here basically you have the approximated surfaces; it can be your ellipsoid or your spheroid, and you are transferring this information onto these maps, so that a map projection conversion of curvilinear surface coordinates to the planar coordinate system is required. Projection converts the coordinate system with distortions such as area, shape, direction, and distance. Some projections preserve two properties, some preserve none of the above, but attempt to minimize distortion in all four. So, we will have a brief introduction to this map projection because time is limited in this particular GIS course. So, if you are interested, then you can refer to my videos from the remote sensing and GIS course, where this map projection is explained in detail. So now we have the datum, which is a set of parameters defining a coordinate system and a set of control points whose geometric relationships are known either through measurement or calculation. Map projections can be perspective or non-perspective depending on their method of construction. Perspective projections are 2D representations of the entire globe or part of it perceived on the basis of the following criteria.



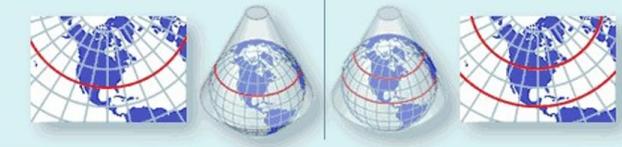
Type of projection plane. The position of the plane of projection, the position of the light source or projection point, and non-perspective projections are developed mathematically by integrating and modifying other projections. So, we will be seeing examples of perspective and non-perspective projection systems. So, on the basis of the type of projection plane, the two-dimensional planes on which the graticules are projected can be of different types: cylindrical, conical, azimuthal, or zenithal projection systems. Here we have put the globe inside this particular paper, and then after the projection,

Types of Map Projections

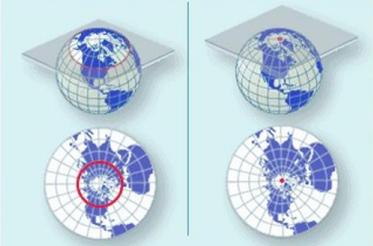

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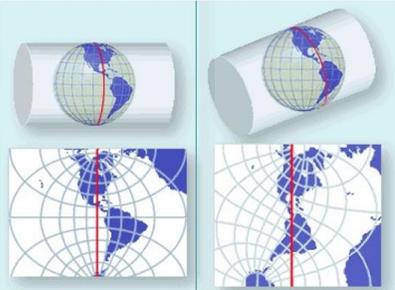
Cylindrical Projection: tangent and secant aspects



Conic Projection: tangent and secant aspects



Azimuthal Projection: tangent and secant aspects



Cylindrical Projection: transverse and oblique aspects

Reference: <http://geokov.com/education/map-projection.aspx>

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We consider that the light is coming from the geocenter and will be projected onto this paper. Once you open the paper, you will find this type of map. So, this is called a cylindrical projection. Once you see this conical projection system. So, here basically a cone is used, and this equator you see here is the place where this paper is touching the cone. So, this area will be the best-represented area for this conical projection. Once you open it, your paper will be like this. Once you have azimuthal projection, light is falling on this paper from here. So, once you open, you will have this kind of representation. So, whether it is the equator or whether it is the pole, depending on that, you will have the equatorial case and the polar case. On the basis of the position of the projection plane, the position at which the two-dimensional plane of projection touches the surface on which the graticules are projected can produce projections of the following types. So, here you can see one by one: this is cylindrical, this is conical, this is azimuthal, this is a cylindrical projection, and again the transverse and oblique aspects. On the basis of the position of the light source or projection point, the point of perception of the source of the light or from where the globe is looked at can be of the following types. So, the first one is the Gnomonic projection. So, this is the first one here. You can see the light source coming from the center, and then this is extended here, and you will have this kind of

representation. This is a stereograph. So, here light is coming from the other end of the pole, and this is the equator, and this is how it will be projected. Now, in orthographic projection, the light source, which is coming from this direction, will be projected here orthographically. Non-perspective projections: The projections are not developed on the basis of the perception of the projection plane from any point or any source of light. So, these are constructed mathematically upon modification of the existing projection and considering different factors and conditions so that the maximum of the projection properties, like shape, area, distance, direction, can be preserved. So, we also discussed in the previous slides some of the projection systems, let us say, preserving one of the parameters. As we discussed in the previous few slides, some of the projections are capable of handling one parameter. They best represent this one of the parameters, but when we talk about the non-perspective, we are not using the perception of the projection, and we did not consider any point of light source. So, in such cases, this particular projection system is able to manage all these properties. So, some of the common examples are the sinusoidal projection and the international map projection for the entire globe. So, this will be the best way to represent the Earth, and you will have better approximation because all these values, like shape, size, and direction, are preserved. So, one of the projections of non-perspective is the UTM. It uses a two-dimensional Cartesian coordinate system to give a location on the Earth's surface.

It is derived from the cylindrical Mercator projection and integrated with the international map projection series to develop a coordinate system where almost the entire globe can be represented while conserving the maximum of properties. In UTM, the globe is divided into 60 zones in each hemisphere, each spanning 6 degrees of latitude. 8 degrees of longitude. Each UTM zone has its own central meridian from which it spans 3 degrees west and 3 degrees east of that central meridian. Longitude-wise, the range starts from 180 degrees west to 180 degrees east, so minus 180 to plus 180. Latitude, the range starts from 0 to 90 degrees north and south, with the same size of the zone, but above 90 degrees to the pole, the size of the extent of the grid changes due to height exaggeration. Used most commonly in GIS platforms for defining the projection of the data. Because whenever you use a satellite image or any parameter derived from remote sensing or conventional techniques, all the maps should be in the same reference system; only then will you be able to overlay them together and run a query to get the answers. So, this is an example of a UTM grid; here you can see how these grids are divided. Now we will talk about spatial data analysis, After we have converted our data to a reference system, we have latitude and longitude.

Now comes how we will analyze this information, these maps, or these datasets in the GIS environment. So, we will talk about spatial data analysis. So, what type of relationship exists between geographic features, and how do we express them? So, to understand spatial relationships and patterns. We have a spatial analysis to understand

our world, mapping where things are, how they relate, what it all means, and what action to take next. So, once you have the information, you can go for the decision support system. For geographic pattern finding, optimum routes, site selection, and advanced predictive modeling, whether a landslide is going to occur at a particular location can be modeled, and similarly, many other hazards can be analyzed, and the predictive modeling can be developed correctly. One of the important aspects of spatial data analysis is understanding where. Where is my office located? Where are my delivery trucks?

So, how far is it from one place, whether it is north of my home or south of my home? Then, measure size, shape, and distribution. How long is the river? How tall is the building? Determine how places are related. Which rivers are within 10 miles of a pipeline? Have other crimes occurred at this particular location? Finding the best location and path, the best route to travel, the best corridor to build a pipeline, or the best location to site a new store. Detecting and quantifying patterns: where are the clusters of high expenditure on alcohol, where are the hotspots of cancer deaths, making predictions: how will a forest fire spread based on vegetation, wind speed, or wind direction; how will store size and travel distance attract or distract customers? So, all this can be done in a GIS environment. And, once we talk about GIS, we have geospatial, spatial, or geographic data. And, once we have the spatial or geographic data, we can perform the spatial data analysis, and this can be understood very well. So, this is one of the examples of special functions that are available or possible in a GIS environment. So, let us say I have a few points here; all these blue colors are the points, and I want to make a buffer. So, in a GIS environment, I will just give a command that I need a buffer of 1 meter around this particular point; then, this will be automatically generated. Here, this is a road network, or maybe you can consider this as a river system, and we wanted to know how much area will be affected by this river. or maybe we want to know that this is a single-lane road, and we are trying to convert it to a six-lane road. How much area do we have to acquire for this process?

So, in such cases, what we will do is just run the buffer. So, the buffer of the polygons or the polylines is another example here; you have a polygon, and we want to make or extend the boundary of a particular one. Organization is So, because of the population and the work culture, we need to make more offices in this region. So, how can we uniformly acquire the knowledge to expand this particular campus? So, in that case, the buffer will help you determine how much area you need to acquire to increase the size of a particular campus or building. So, this kind of analysis can be done in GIS, and it will help you to ease your work at the field level. Some additional functions are given here. So, here A disjoint B, A contains B, A overlaps B, A inside B, then you have A touching B, A covering B. Then A equals B, and then A approximately covers B. So, all these functions can be done in GIS environment once you have 2 sets of data captured from 2 different groups, and then you are trying to use them together. So, maybe you have to

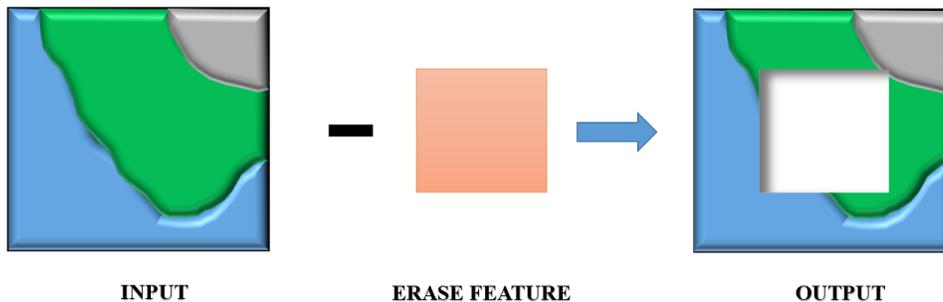
extract the common boundary for both data sets, and then you will be able to perform any analysis. So, some of the examples here are the erase function. So, here we used to remove undesired feature classes in the input or output data. So, let us say you want to remove this particular area from this map.

So, you use the erase function, then identify overlay, which is to update the existing database with additional information. Here you have 2 data sets, 1 and 2, and then you are updating this map.

Spatial Overlay Functions: Erase (Coverage)



Used to remove undesirable features/classes in input/output data.



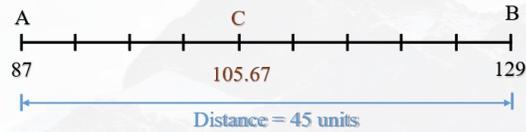
An intersect overlay is used to extract information from the database. So, here is the intersect feature, and this is the database. So, wherever you have a common boundary, you will have the output; then, the union overlay.

So, here it is to update the existing data with additional information; the areal extent includes both of them. So, initially, we did not consider this, but when you go for a union, the boundaries will be used here. Then update the overlay used to generalize the existing feature or database with additional information; the area extent may change. So, here you can see that additional information will be added. Then one of the most important aspects of spatial analysis is interpolation because many times we collect information in the field, let us say water quality, all these values are the point values. So, these are specific to a particular location, but in between, we do not have any value. So, to identify what the possible value for these locations is, we can go for the interpolation. So, it is a method of approximating a set of values distributed over space if some values in the set are unknown.

There are two points, A with a value of 87 and B with a value of 129

Distance between A and B is 45 units

Find the value at an unknown point C at a distance of 20 units from A.



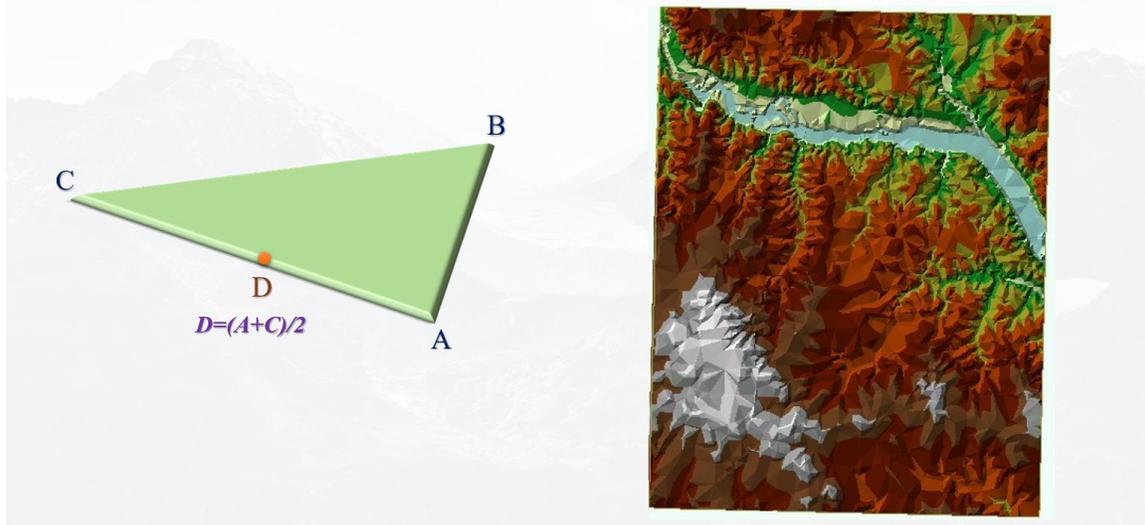
A simple interpolation using two distant known points

At a distance of say 20 units from A:

$$\begin{aligned} \text{Value of C} &= 87 + \left(\frac{129-87}{45} \times 20 \right) \\ &= 87 + 18.67 = 105.67 \end{aligned}$$

Interpolation is a method of approximating a set of values distributed over space when some values of the set are known. Interpolation can be used to estimate elevation, rainfall, temperature, chemical dispersion, or other spatially based phenomena. Interpolation can be performed on a vector using a tin surface model that is the best way because you will have a better representation of the nearest value. So, here is one example. Points A and B are given here. So, point A is 87, point B is 129, and the distance between these two is 45 units. A simple interpolation using two known distance points allows you to identify the value for C. So, there are two points, and the distance between A and B is 45 units. Now find the value at an unknown point C, which is at a distance of 20 units from A. So, this is 20 units.

So, this is very easy. So, you can calculate the value of C; this is 105.67. This is another example where you have three values, and you can calculate the value for D. So, the nearest points would be C and A, and here D can be calculated correctly. A spatial interpolation depends on two major factors: sample points with known values in space and the spatial interpolation scheme or type. So, spatial interpolation can be a global interpolation or a local interpolation. So, remember that depending on the size of your study area, you have to decide whether it is global or local. In global interpolation, every known value is used to determine an unknown value.



In local interpolation, a set of known values is used to determine an unknown value. So, which one will provide a more appropriate or true representation, or will it be a more precise value? That will be your local interpolation. But when the size of your area is quite large and the values are varying in space, then global interpolation can also be used. So, these are some of the spatial functions that are listed here: IDW, Kriging, spline, and spline with barrier. So, these are very commonly used in a GIS environment. So, with this, I will end this lecture, and we will continue this course.

Thank you very much.