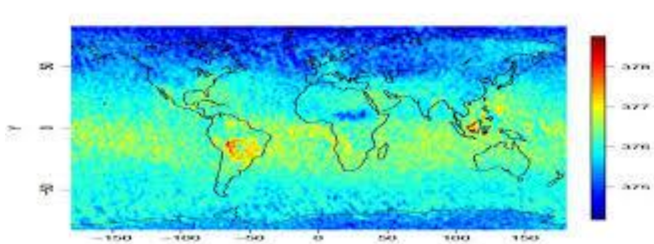
UNITED NATIONS STATISTICS DIVISION (UNSD)

Workshop on Environment Statistics in support of the implementation of the Framework for the Development of Environment Statistics (FDES 2013)

Balaclava, Mauritius

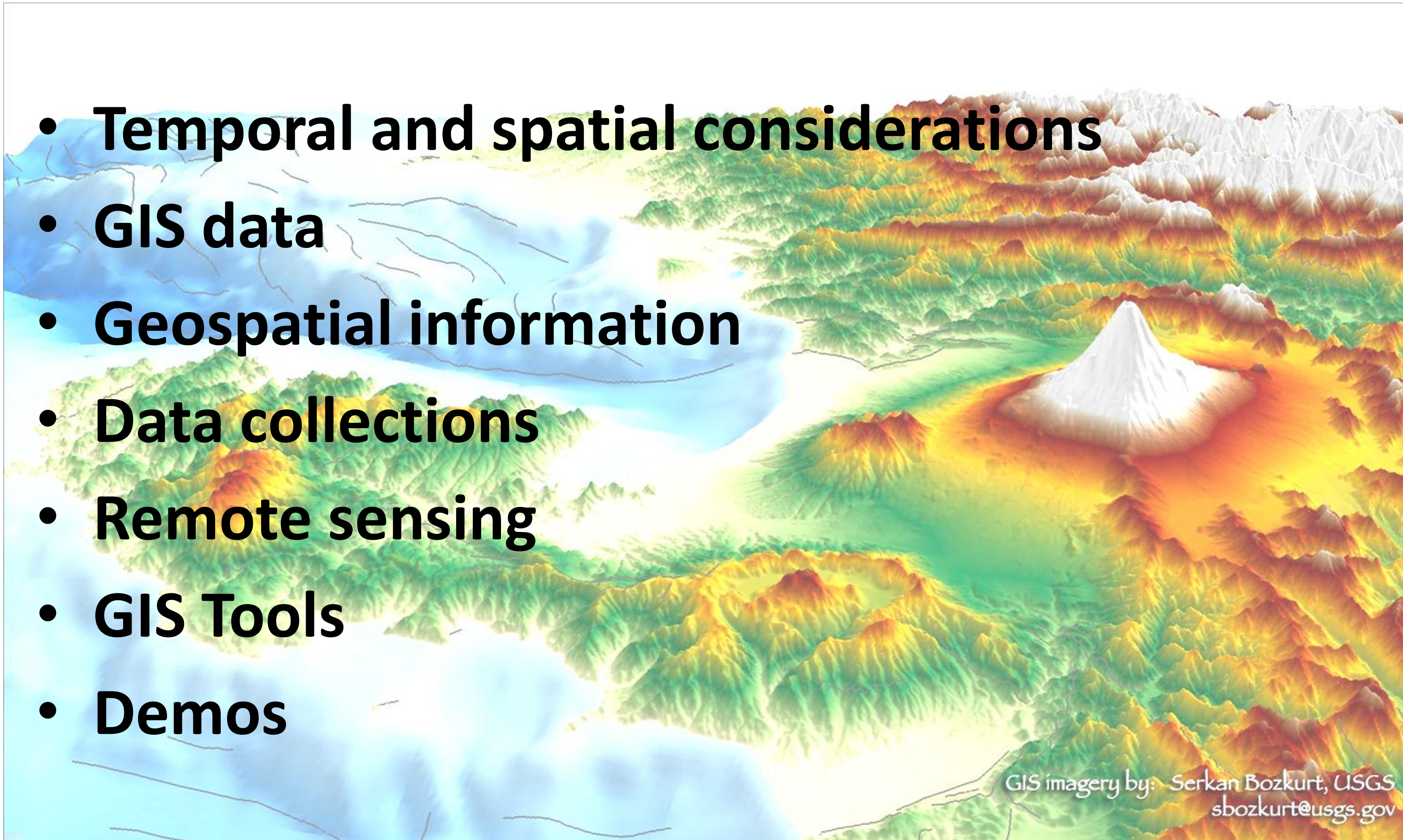
26-29 January 2015

The use of GIS and remote sensing for environment statistics



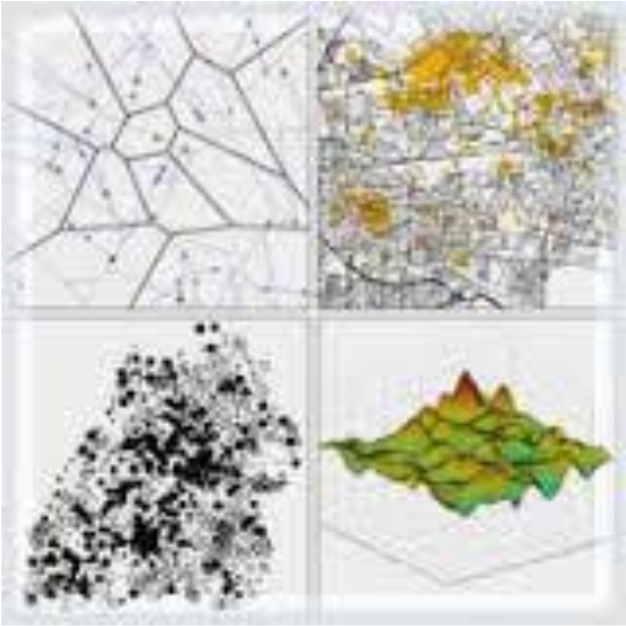
Contents

- Temporal and spatial considerations
- GIS data
- Geospatial information
- Data collections
- Remote sensing
- GIS Tools
- Demos



Temporal and spatial considerations

- From FDES 2013
  - Environment statistics require the simultaneous consideration of a number of temporal and spatial issues.
  - Important to align the temporal aggregations of environmental data with those used in economic and social statistics to ensure their proper integration, often a uniform calendar or fiscal year do not fit the diversity of natural phenomena;
  - therefore the use of different time scales, longer or shorter time periods is also necessary for the aggregation of environmental data over time.



Temporal and spatial considerations

- For example, in fluid environmental phenomena, the temporal dimension is needed since there can be ebbs and flows, droughts and floods, snow and runoffs which all influence measurements.
- Sometimes daily variations and at other times variations seasonal depending on what is being measured. Seasonal variations can be seen in the fluctuations in certain types of fish biomass, surface water levels, ice cap surface or the incidence of fires – monitoring focused more during some months
- Temporal statistics often point out the maximum, the minimum and/or other ways of describing the relevant phenomenon and its levels below or above certain benchmarks, and are not restricted to a sum or an average over a longer period.
- When environmental data are produced at irregular intervals, environment statistics based on these data can still be produced at regular intervals if there are enough data points in each period to do so.

Temporal and spatial considerations

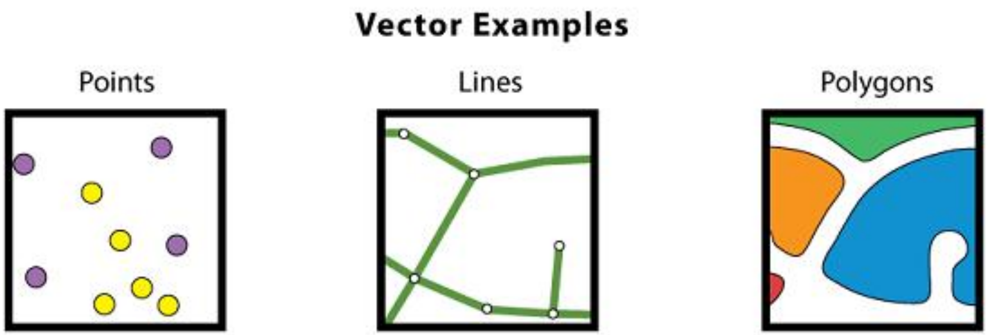
- Spatial consideration
  - occurrence and impacts of environmental phenomena are distributed through space without regard for political-administrative boundaries.
  - The most meaningful spatial units for environment statistics are natural units, such as watersheds, ecosystems, eco-zones, landscape or land cover units; or management and planning units based on the natural units, such as protected areas, coastal areas or river basin
  - However, admin regions (e.g districts) can be combined with natural units.

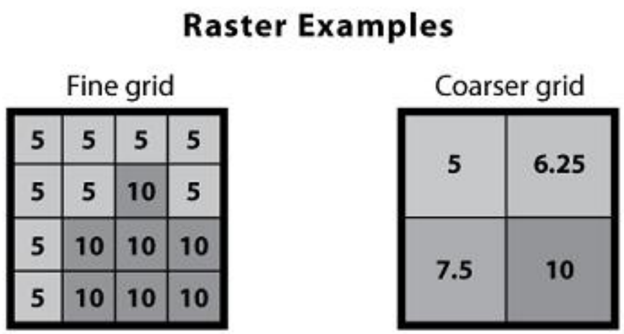
GIS Data
Vector vs. Raster

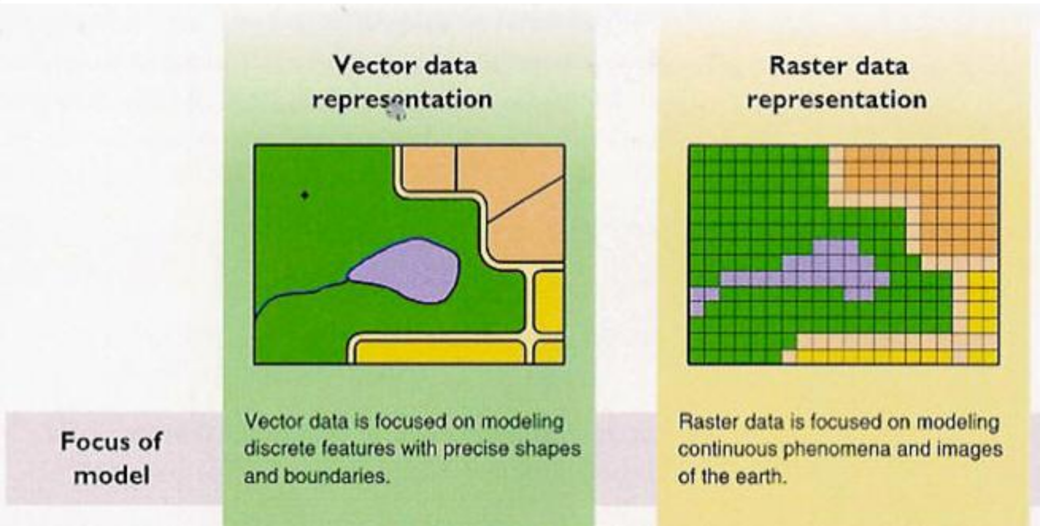
Spatial data that can be visualized in a GIS comes in two formats, vector and raster

	Description	Examples	Common File Extensions
vector	uses coordinate geometry and is represented as points, lines, or polygons.	contour lines; boundaries that delineate a watershed	.shp, .svg.
raster	digital image represented by grid cells with values (pixel sizes)	digital elevation model (DEM); satellite imagery	.tif, .img, ESRI grid

GIS Data - Vector vs. Raster







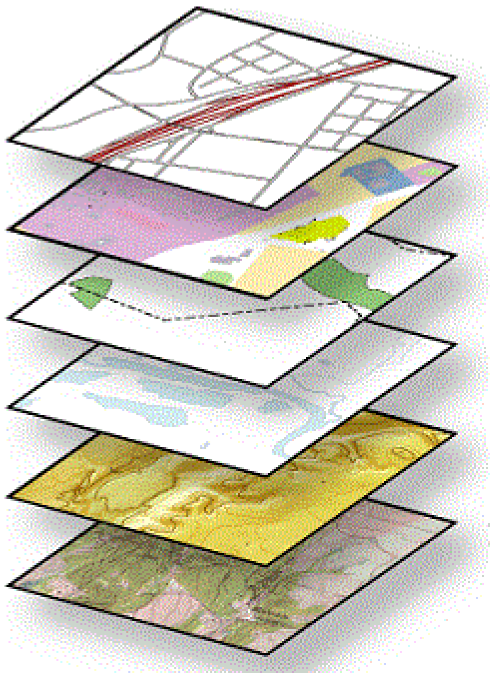
Geospatial information

- Geospatial information presents the location and characteristics of different attributes of the atmosphere, surface and sub-surface.
- It is used to describe, display and analyze data that have discernible spatial aspects, such as land use, water resources and natural disasters.
- Geospatial information allows for the visual display of different statistics in a map-based layout, which can make it easier for users to work with and understand the data.

Geospatial information

- The complexity of current environmental issues

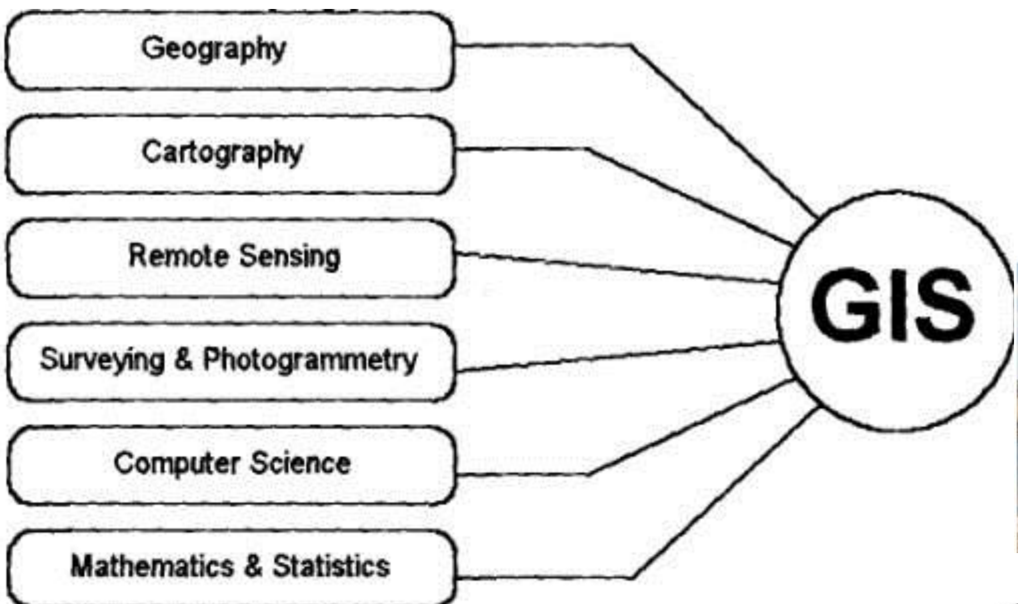
  (e.g., climate change, biodiversity loss, ecosystem health, natural disaster frequency and intensity, population growth, food and water shortages, etc.) increasingly calls for the integration of geospatial information, statistics and sectoral data for more effective and efficient monitoring of progress in the environmental pillar of sustainable development.
- Geographic Information Systems (GIS) can help establish the links between different types and layers of data by providing powerful tools for storage and analysis of spatial data and by integrating databases from different sectors in the same format and structure.

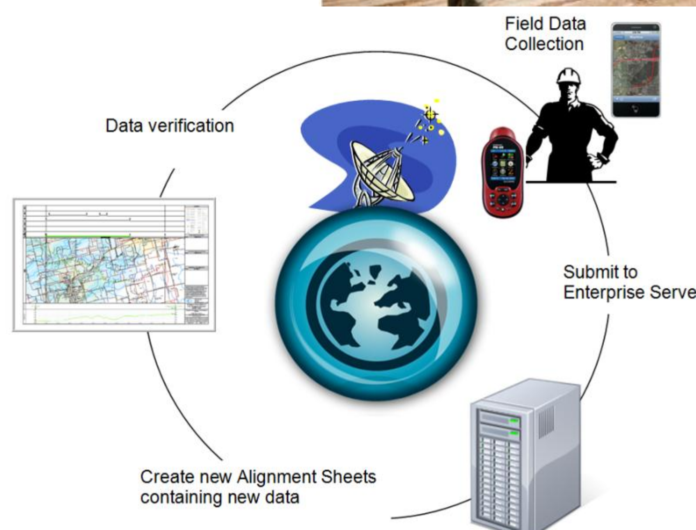


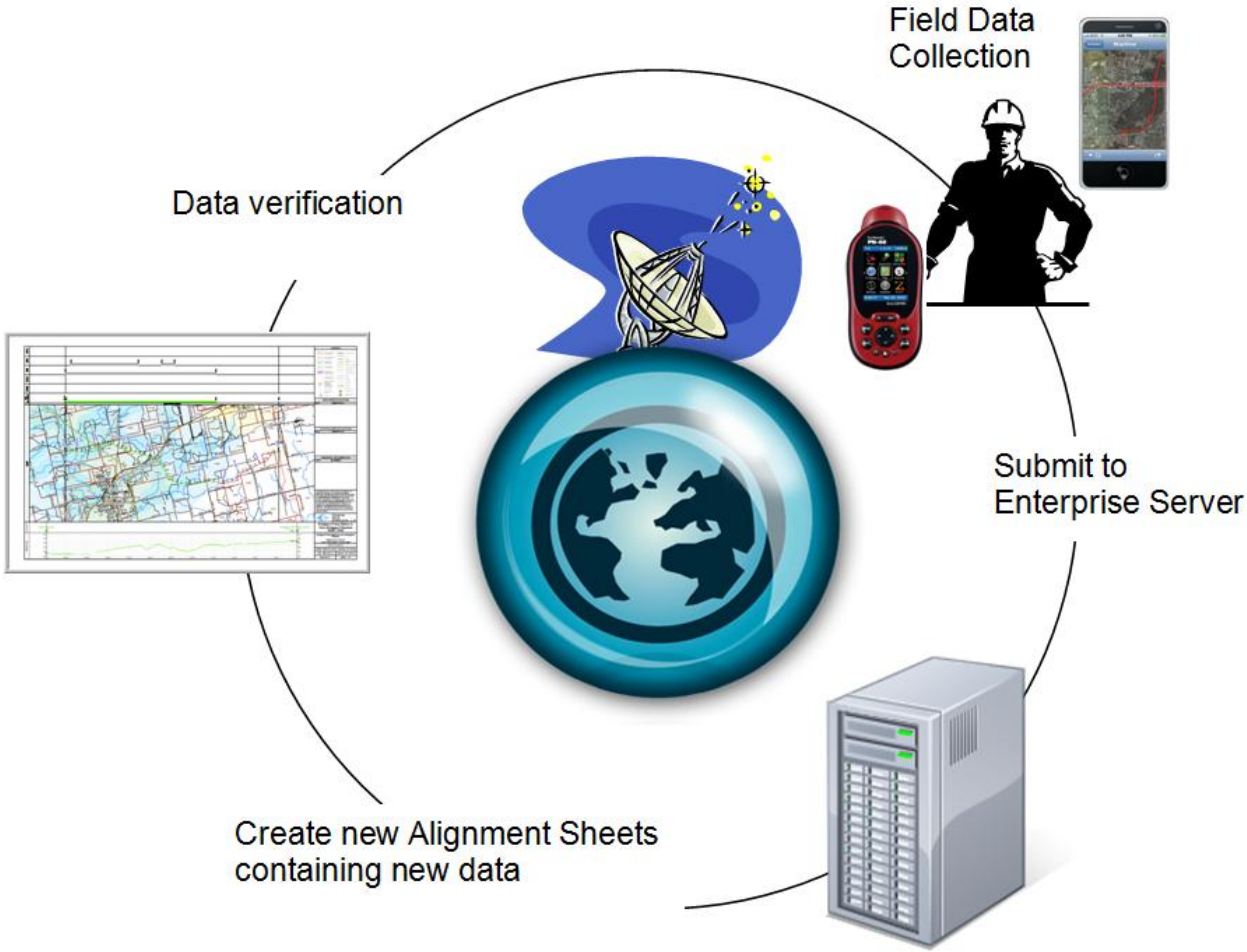
Geospatial information

- A GIS is a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information.
- Geospatial data can be acquired using a variety of technologies such as Global Positioning System (GPS) and Remote Sensing satellites.
- Land surveyors, census takers, aerial photographers, police, and even average citizens with a GPS enabled cell phone can collect geospatial data using GPS or street addresses that can be entered into GIS.
- The attributes of the collected data, such as land-use information, demographics, landscape features, or crime scene observations, can be entered manually or, in the case of a land survey map, digitized from a map format to a digital format by electronic scanning.

GIS data collections







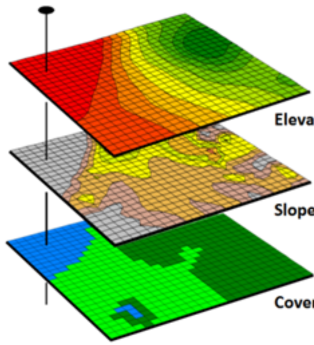
Field Data
Collection
Data verification
Submit to
Enterprise Server
Create new Alignment Sheets
containing new data

A Mathematical Structure for Spatial Analysis

Geotechnology → RS – **GIS** – GPS

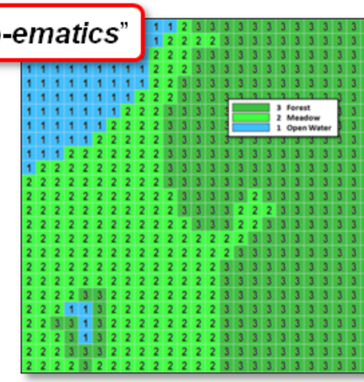
Mapping/Geo-Query *(Discrete, Spatial Objects)* – *(Continuous, Map Surfaces)* **Map Analysis/Modeling**

"Map-*ematics*"



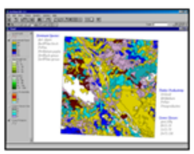
1) Maps as Quantitative Data

*Vector & **Raster**, Aggregated & **Disaggregated***
*Qualitative/**Quantitative** & Choropleth/**Isopleth***



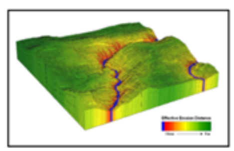
2) Spatial Analysis Operations

Traditional GIS → **Spatial Analysis**



Forest Inventory Map

- Points, Lines, Polygons
- Discrete Objects
- Mapping and Geo-query



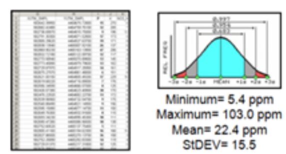
Erosion Potential (Surface)

- Cells, Surfaces
- Continuous Geographic Space
- Contextual Spatial Relationships

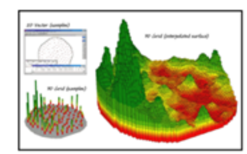
Basic GridMath & Map Algebra *(+ - * /)*
Advanced GridMath *(Math, Trig, Logical Functions)*
Map Calculus *(Spatial Derivative, Spatial Integral)*
Map Geometry *(Euclidian Proximity, Narrowness, Effective Proximity)*
Plane Geometry Connectivity *(Optimal Path, Optimal Path Density)*
Solid Geometry Connectivity *(Viewshed, Visual Exposure)*
Unique Map Analytics *(Contiguity, Size/Shape/Integrity, Masking, Profile)*

3) Spatial Statistics Operations

Traditional Statistics → **Spatial Statistics**



- Mean, StDev (Normal Curve)
- Central Tendency
- Typical Response (scalar)



Phosphorous Distribution (Surface)

- Map of the Variation (gradient)
- Spatial Distribution
- Numerical Spatial Relationships

Basic Descriptive Statistics *(Min, Max, Median, Mean, StDev, etc.)*
Basic Classification *(Reclassify, Binary/Ranking/Rating Suitability)*
Unique Map Descriptive Statistics *(Roving Window Summaries)*
Map Comparison *(Joint Coincidence, Statistical Tests)*
Surface Modeling *(Density Analysis, Spatial Interpolation)*
Advanced Classification *(Map Similarity, Maximum Likelihood, Clustering)*
Predictive Statistics *(Map Correlation/Regression, Data Mining Engines)*

Remote sensing

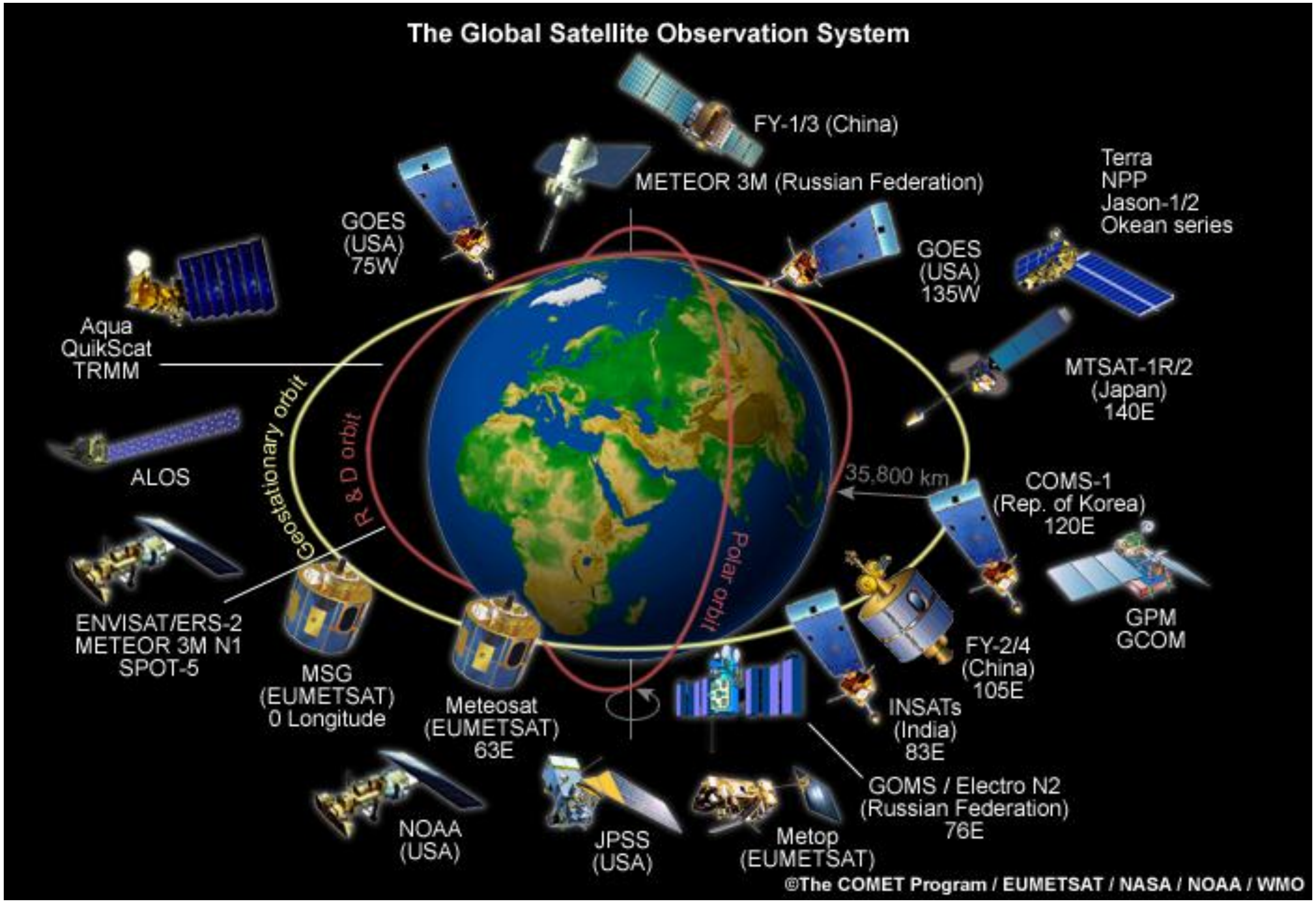
- Remote sensing data from satellites are acquired digitally and communicated to central facilities for processing and analysis in GIS.
- Digital satellite images, for example, can be analyzed in GIS to produce maps of land cover and land use.
- When different types of geospatial data are combined in GIS (e.g., through combining satellite remote sensing land use information with aerial photographic data on housing development growth), the data must be transformed so they fit the same coordinates.
- GIS uses the processing power of a computer, together with geographic mapping techniques (cartography), to transform data from different sources onto one projection and one scale so that the data can be analyzed together

Remote sensing

- Remote sensing is a technique for gathering information about an object without coming into physical contact with it.
- It is the quantitative analysis of digital information where measurements can be made from ground, aircrafts or satellites. The information is carried by electromagnetic radiation.
- With remote sensing, skills are needed in digital image analysis where computer programming, image display tools and statistics, etc., are required for interdisciplinary work that might involve scientists and experts in various fields - biology, climatology, geology, atmospheric science, chemistry, oceanography, and more.
- With satellite remote sensing, global issues can be addressed by monitoring regional and global changes

- Source: Government Accountability Office, (2004), *Geospatial Information: Better Coordination Needed to Identify and Reduce Duplicative Investments,* http://www.gao.gov/assets/250/243133.pdf34

Satellites


The Global Satellite Observation System
FY-1/3 (China)
METEOR 3M (Russian Federation)
Terra
NPP
Jason-1/2
Okean series
GOES
(USA)
75W
GOES
(USA)
135W
Aqua
QuikScat
TRMM
MTSAT-1R/2
(Japan)
140E
Geostationary orbit
R & D orbit
35,800 km
ALOS
COMS-1
(Rep. of Korea)
120E
Polar orbit
GPM
GCOM
ENVISAT/ERS-2
METEOR 3M N1
SPOT-5
FY-2/4
(China)
105E
MSG
(EUMETSAT)
0 Longitude
Meteosat
(EUMETSAT)
63E
INSATs
(India)
83E
GOMS / Electro N2
(Russian Federation)
76E
NOAA
(USA)
JPSS
(USA)
Metop
(EUMETSAT)
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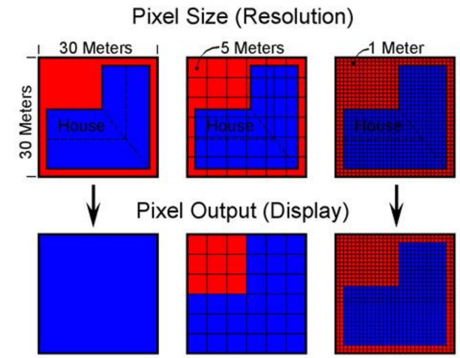
Satellites

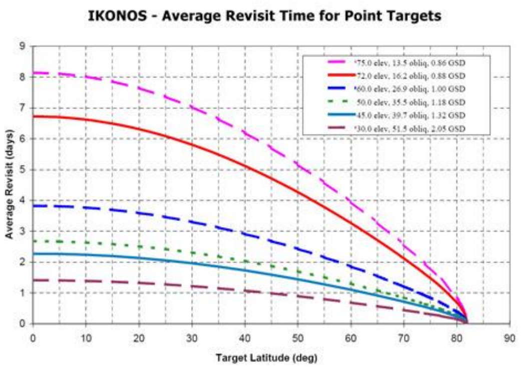
Positions around the globe

Resolution of satellite data

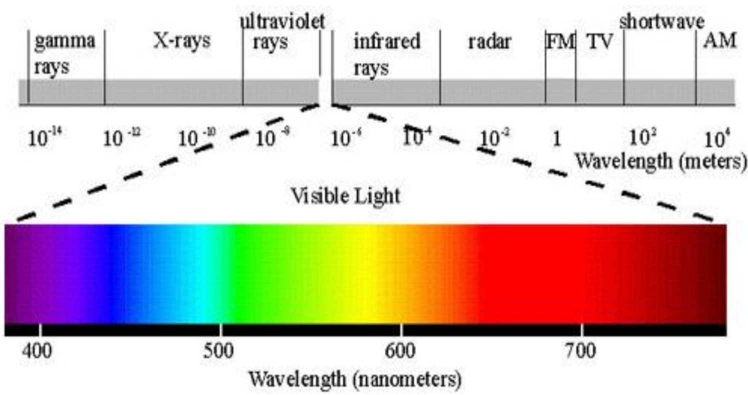
- The most common characterization of different satellite remote sensing (RS) systems results from the systems diverse spatial, temporal and spectral resolutions.
- **Spatial Resolution**
- The spatial resolution specifies the pixel size of satellite images covering the earth surface.
  - High spatial resolution: 0.41 - 4 m
  - Low spatial resolution: 30 - > 1000 m



- **Temporal Resolution**
- The temporal resolution specifies the revisiting frequency of a satellite sensor for a specific location.
  - High temporal resolution: < 24 hours - 3 days
  - Medium temporal resolution: 4 - 16 days
  - Low temporal resolution: > 16 days

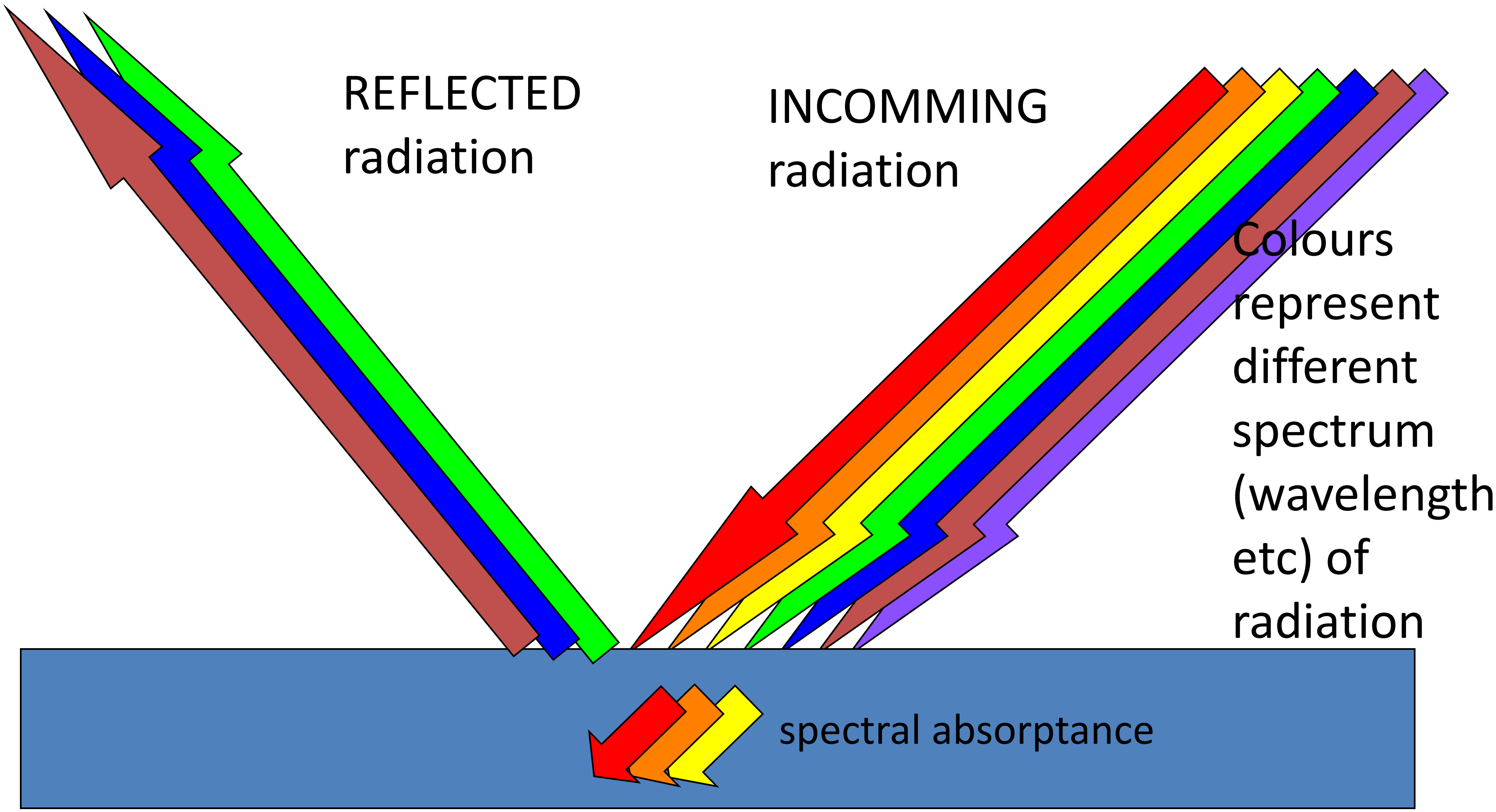


- **Spectral Resolution**
- In the first instance, a sensor's spectral resolution specifies the number of spectral bands in which the sensor can collect reflected radiance. But the number of bands is not the only important aspect of spectral resolution. The position of bands in the electromagnetic spectrum is important, too.
  - High spectral resolution: - 220 bands
  - Medium spectral resolution: 3 - 15 bands
  - Low spectral resolution: - 3 bands

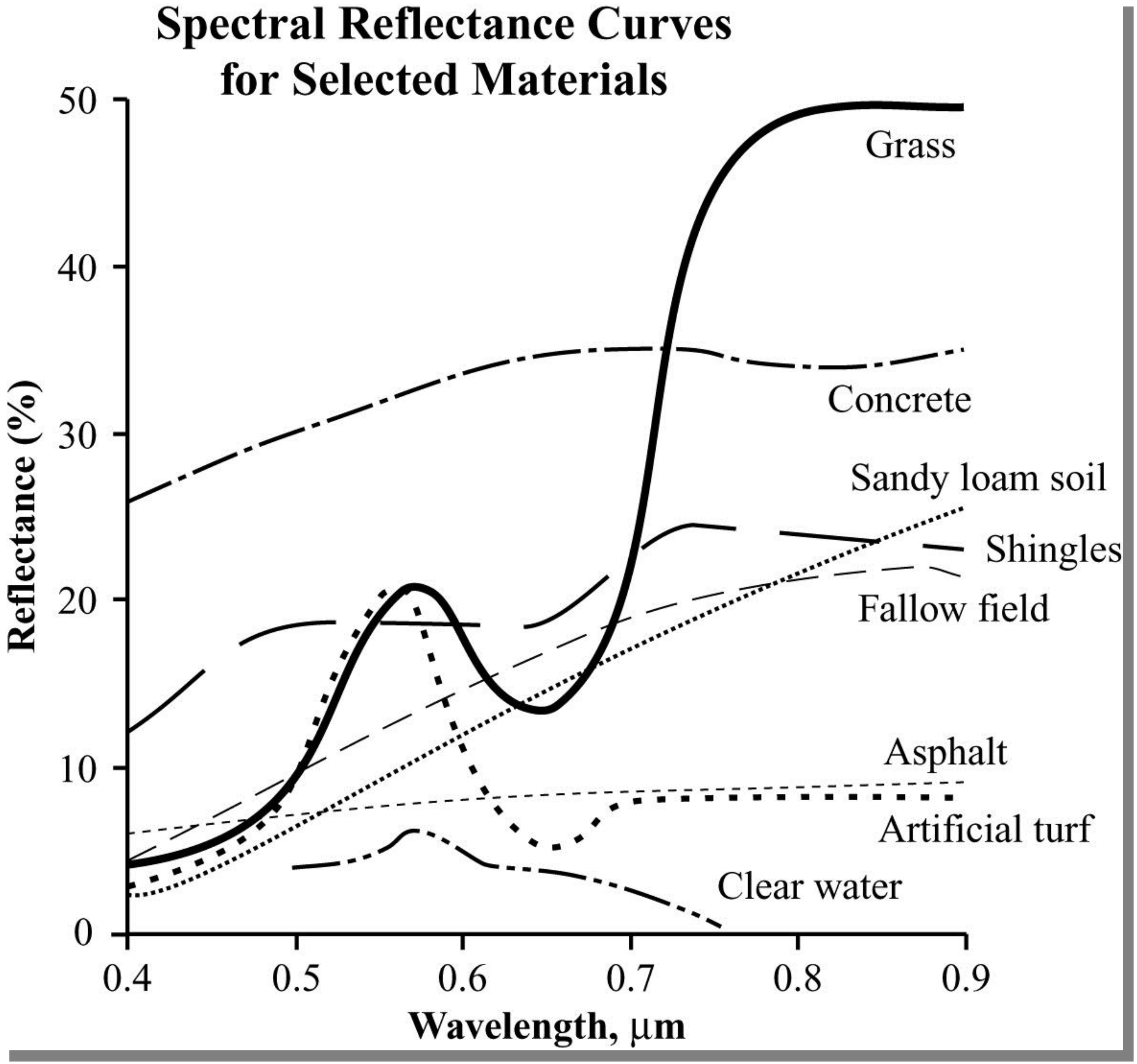


- For example the temporal resolution of a satellite like Landsat is 16 days, while for a NOAA satellite it is four hours. So the NOAA satellite has a **higher temporal resolution** than Landsat, but a **lower spatial resolution** (1.1 km versus 30 meters).

Spectral Reflectance



Surface of the earth and its environment – lakes, ocean, settlements etc



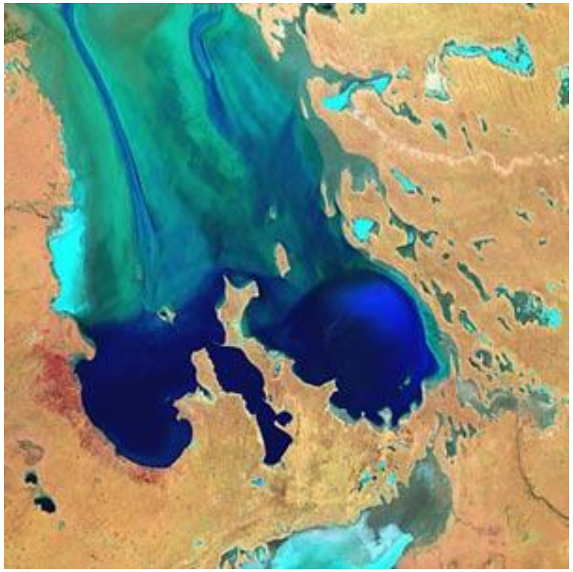
Spectral Reflectance Curves
for Selected Materials
50
40
30
20
10
0
Reflectance (%)
0.4
0.5
0.6
0.7
0.8
0.9
Wavelength, μm
Grass
Concrete
Sandy loam soil
Shingles
Fallow field
Asphalt
Artificial turf
Clear water

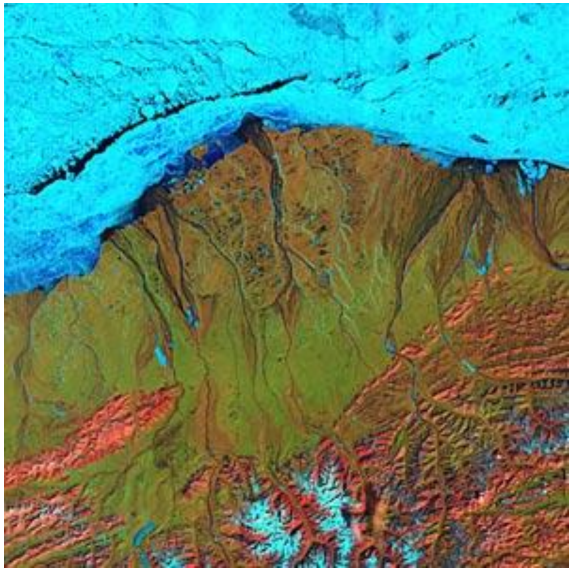
Landsat Thematic Mapper Bands and their Uses

- Band 1 (Blue: 0.45 - 0.52 μm)
  - good water penetration
  - differentiating soil and rock surfaces from vegsmoke plumes
  - most sensitive to atmospheric haze
- Band 2 (Green: 0.52 - 0.60 μm)
  - water turbidity differences
  - sediment and pollution plumes
  - discrimination of broad classes of vegetation
- Band 3 (Red: 0.63 - 0.69 μm)
  - strong chlorophyll absorption (veg. vs. soil)
  - urban vs. rural areas

Landsat Thematic Mapper Bands and their Uses

- Band 4 (NIR1: 0.76 - 0.90 μm)
  - different vegetation varieties and conditions
  - dry vs. moist soil
  - coastal wetland, swamps, flooded areas
- Band 5 (NIR2: 1.55 - 1.75 μm)
  - leaf-tissue water content
  - soil moisture
  - snow vs cloud discrimination
- Band 6 (Thermal: 10.4 - 12.5 μm)
  - heat mapping applications (coarse resolution)
  - radiant surface temperature range: -100°C to +150°C
- Band 7 (NIR3: 2.08 - 2.35 μm)
  - absorption band by hydrous minerals (clay, mica)
  - lithologic mapping (clay zones)





GIS Tools

- 1 Open source software
  - Desktop GIS
  - Other geospatial tools
    - Web map servers
    - Spatial database management systems
    - Software development frameworks and libraries (for web applications)
    - Software development frameworks and libraries (non-web)
    - Cataloging application for spatially referenced resources
    - Other tools
- 2 Notable commercial or proprietary GIS software
  - Desktop GIS
    - Companies with high market share
    - Companies with minor but notable market share
  - GIS as a service
    - Companies with high market share
  - Spatial DBMS
  - Spatial Data Transformation Tools

(Source: http://en.wikipedia.org/wiki/List_of_geographic_information_systems_software)

Free GIS tools - (Non Exhaustive list)

- GRASS GIS – Originally developed by the U.S. Army Corps of Engineers, open source: a complete GIS
- SAGA GIS – System for Automated Geoscientific Analysis- a hybrid GIS software. SAGA has a unique Application Programming Interface (API) and a fast growing set of geoscientific methods, bundled in exchangeable Module Libraries.
- Quantum GIS – QGIS is an Open Source GIS that runs on Linux, Unix, Mac OS X, and Windows.
- MapWindow GIS – Free, open source GIS desktop application and programming component.
- ILWIS – ILWIS (Integrated Land and Water Information System) integrates image, vector and thematic data.
- uDig – Open source GIS desktop application (API and source code (Java) available).
- gvSIG – Open source GIS written in Java.
- JUMP GIS / OpenJUMP – (Open) Java Unified Mapping Platform (the desktop GIS OpenJUMP, SkyJUMP, deeJUMP and Kosmo emerged from JUMP

Free GIS tools - (Non Exhaustive list)

- **WebMap Server**
  - Mapnik - C++/Python library for rendering - used by OpenStreetMap
  - GeoServer
  - MapGuide Open Source – Web-based mapping server.
  - MapServer – Web-based mapping server, developed by the University of Minnesota.
- **Spatial Database Management Systems**
  - PostGIS – Spatial extensions for the open source PostgreSQL database, allowing geospatial queries.
  - TerraLib is a spatial DBMS and also provides advanced functions for GIS analysis.
  - SpatiaLite – Spatial extensions for the open source SQLite database, allowing geospatial queries.
- **Software Development Frameworks and Libraries (non-web)**
  - GeoTools – Open source GIS toolkit written in Java, using Open Geospatial Consortium specifications.
  - GDAL / OGR
  - Orfeo toolbox
- **Software Development Frameworks and Libraries (for web applications)**
  - OpenLayers – open source AJAX library for accessing geographic data layers of all kinds, originally developed and sponsored by MetaCarta.
  - MapFish
  - GeoBase (Telogis GIS software) - Geospatial mapping software available as a Software development kit, which performs various functions including address lookup, mapping, routing, reverse geocoding, and navigation. Suited for high transaction enterprise environments.
- **Cataloging application for spatially referenced resources**
  - GeoNetwork opensource – A catalog application to manage spatially referenced resources

Commercial GIS (Non exhaustive list)

- Autodesk – Products include Map 3D, Topobase, MapGuide and other products that interface with its flagship AutoCAD software package.
- Bentley Systems – Products include Bentley Map, Bentley Map View and other products that interface with its flagship MicroStation software package.
- ERDAS IMAGINE by ERDAS Inc; products include Leica Photogrammetry Suite, ERDAS ER Mapper, and ERDAS ECW JPEG2000 SDK (ECW (file format))are used throughout the entire mapping community (GIS, Remote Sensing, Photogrammetry, and image compression).
- Esri – Products include ArcView 3.x, ArcGIS, ArcSDE, ArcIMS, ArcWeb services and ArcGIS Server.
- Intergraph – Products include G/Technology, GeoMedia, GeoMedia Professional, GeoMedia WebMap, and add-on products for industry sectors, as well as photogrammetry.
- MapInfo by Pitney Bowes – Products include MapInfo Professional and MapXtreme.
- Smallworld – developed in Cambridge, England (Smallworld, Inc.) and purchased by General Electric and used primarily by public utilities.

Demo on GIS

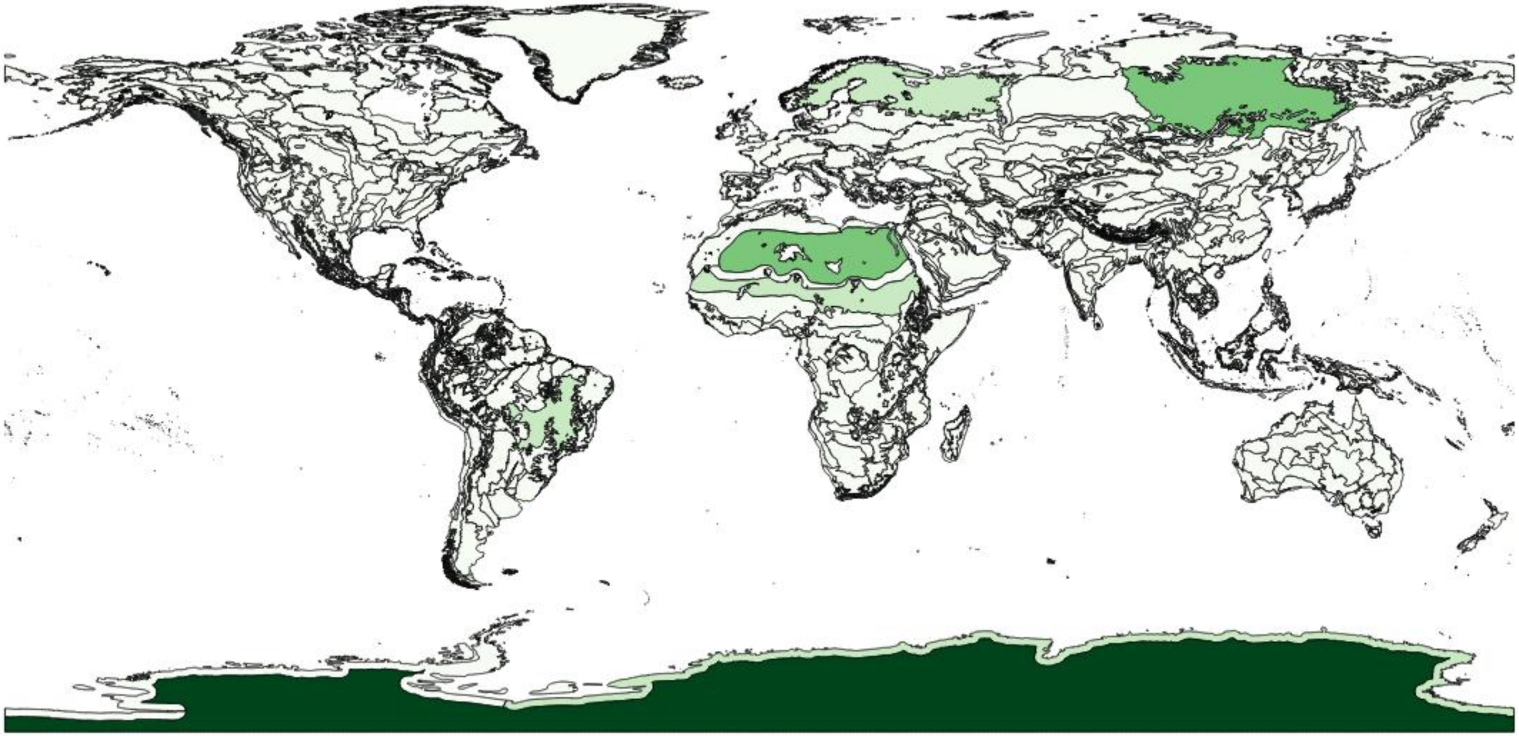
- QGIS - A Free and Open Source Geographic Information System (http://www.qgis.org/en/site/)
- Refer to QGIS Tutorial: http://www.qgistutorials.com/en/
- A simple map with attributes for environment statistics

Some data sources for Africa

- Data Websites: Africa: https://lib.stanford.edu/gis-branner-library/data-websites-africa
- AfricaMap: http://worldmap.harvard.edu/africamap/

Example

- Eco regions



Example attribute table

- Tabular data

wkt_geom	OBJECTID	RASTRWT	F_AREA	Class	ID	Hectares	Shape_Leng	Shape_Area	DistrictCd	EsaTypeCo
POLYGON	1	0.5	1274987	Low	FR0001	127.4069	19323.0013	1274069.052		FR
POLYGON	2	0.5	7062.393	Low	FR0002	0.70573	381.9399669	7057.298824		FR
POLYGON	3	0.5	5240.4	Low	FR0003	0.523663	308.8429142	5236.630898		FR
POLYGON	4	0.5	6288.48	Low	FR0004	0.628396	336.2744423	6283.960912		FR
POLYGON	5	0.5	9432.72	Low	FR0005	0.942594	454.8827517	9425.942615		FR
POLYGON	6	0.5	3047.067	Low	FR0006	0.304488	210.7387577	3044.879881		FR
POLYGON	7	0.5	12070.27	Low	FR0007	1.20616	525.8803496	12061.60101		FR
POLYGON	8	0.5	18434.4	Low	FR0008	1.84212	759.8344087	18421.20016		FR
POLYGON	9	0.5	58779.01	Low	FR0009	5.873825	3256.430969	58738.25189		FR
POLYGON	10	0.5	10880.4	Low	FR0010	1.087285	652.9846647	10872.85483		FR
POLYGON	11	0.5	10932.78	Low	FR0011	1.092518	783.6396951	10925.18417		FR
POLYGON	12	0.5	5878.531	Low	FR0012	0.587444	433.5656662	5874.437579		FR
POLYGON	13	0.5	76031.57	Low	FR0013	7.597889	1078.576335	75978.88801		FR
POLYGON	14	0.5	14691.67	Low	FR0014	1.468136	1074.869131	14681.35669		FR
POLYGON	15	0.5	21316.23	Low	FR0015	2.130126	1106.481032	21301.26157		FR
POLYGON	16	0.5	195575.6	Low	FR0016	19.54386	8504.877747	195438.5685		FR

THANK YOU