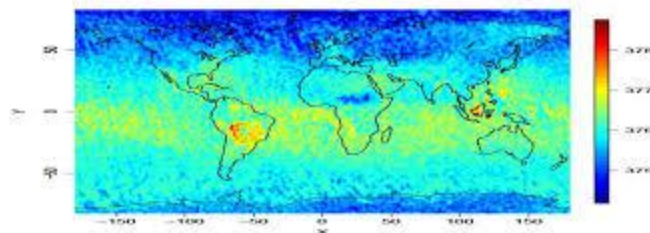




UNITED NATIONS STATISTICS DIVISION (UNSD)

Workshop on Environment Statistics in support of the implementation of the Framework for the Development of Environment Statistics, Arusha, Tanzania, 6-10 July 2015

The use of GIS and remote sensing for environment statistics



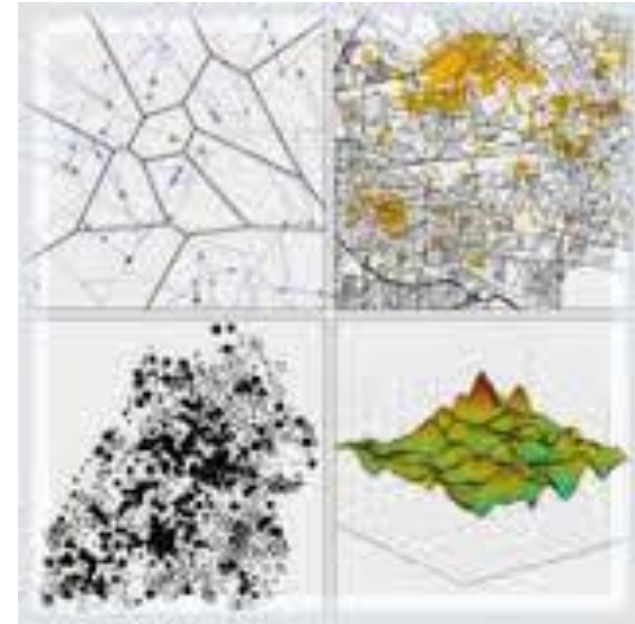
Contents

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

GIS imagery by: Serkan Bozkurt, USGS
sbozkurt@usgs.gov

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.



Spatial and Temporal

- Spatial - Anything/event that occur in space has a spatial dimension – e.g environmental phenomena like air pollution, biodiversity conservation...
- Temporal – anything/event relating to or limited by time, e.g disasters in 2014, hourly PM10 concentration at a specific site...

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 seasonal variations 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.

Geospatial information

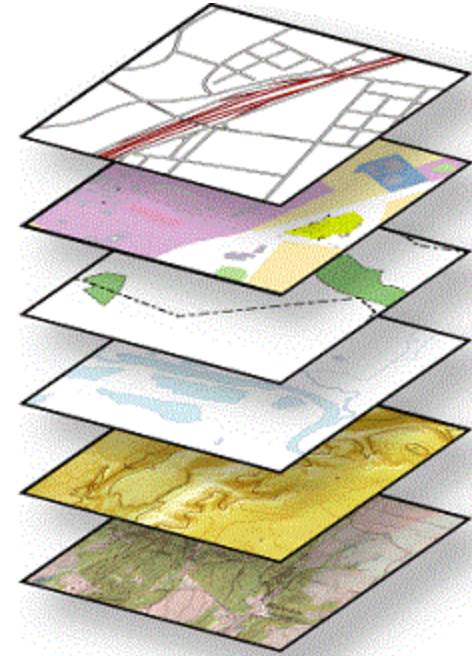
- Geospatial information presents the location and characteristics of different attributes of the atmosphere, surface and sub-surface.
- It is used to describe, display and analyze data that have discernible spatial aspects, such as land use, water resources and natural disasters.
- Geospatial information 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

- A GIS is part of geo-information and 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.

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.



GIS layers of data

GIS Data

Vector vs. Raster

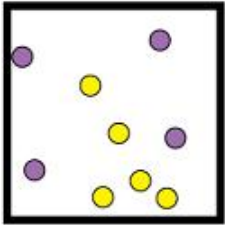
Spatial data that can be visualized in a GIS comes in two formats, vector and raster

	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

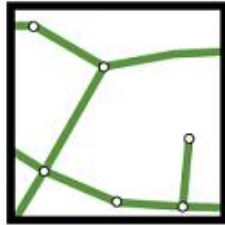
GIS Data - Vector vs. Raster

Vector Examples

Points



Lines



Polygons



Raster Examples

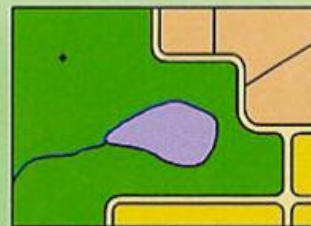
Fine grid

5	5	5	5
5	5	10	5
5	10	10	10
5	10	10	10

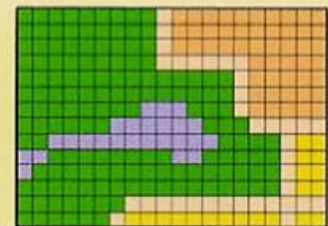
Coarser grid

5	6.25
7.5	10

Vector data representation



Raster data representation

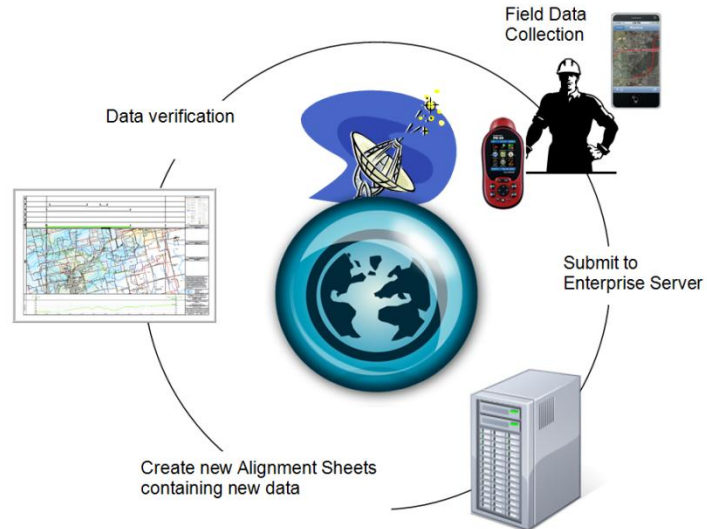
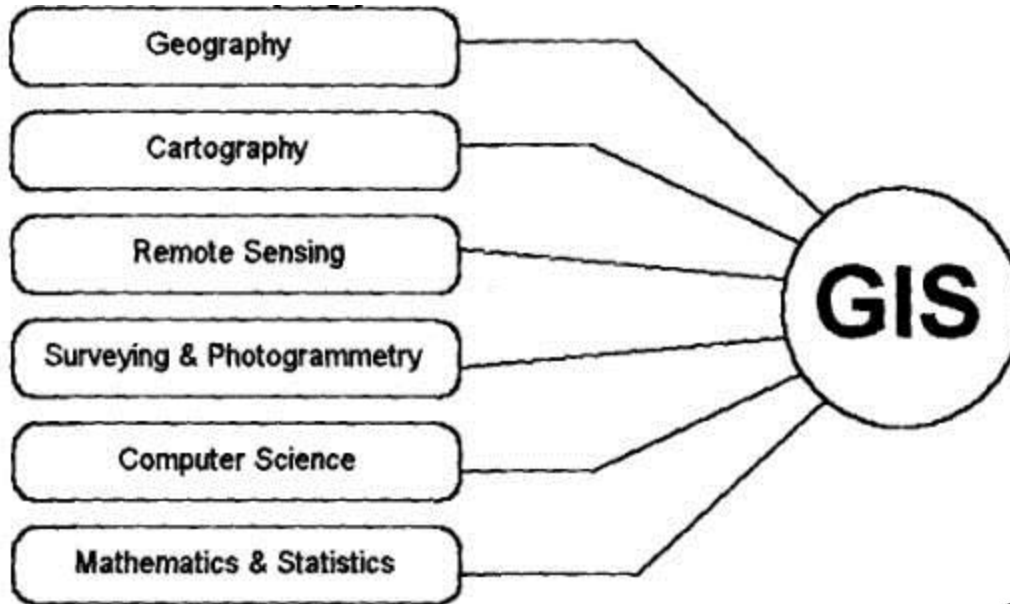


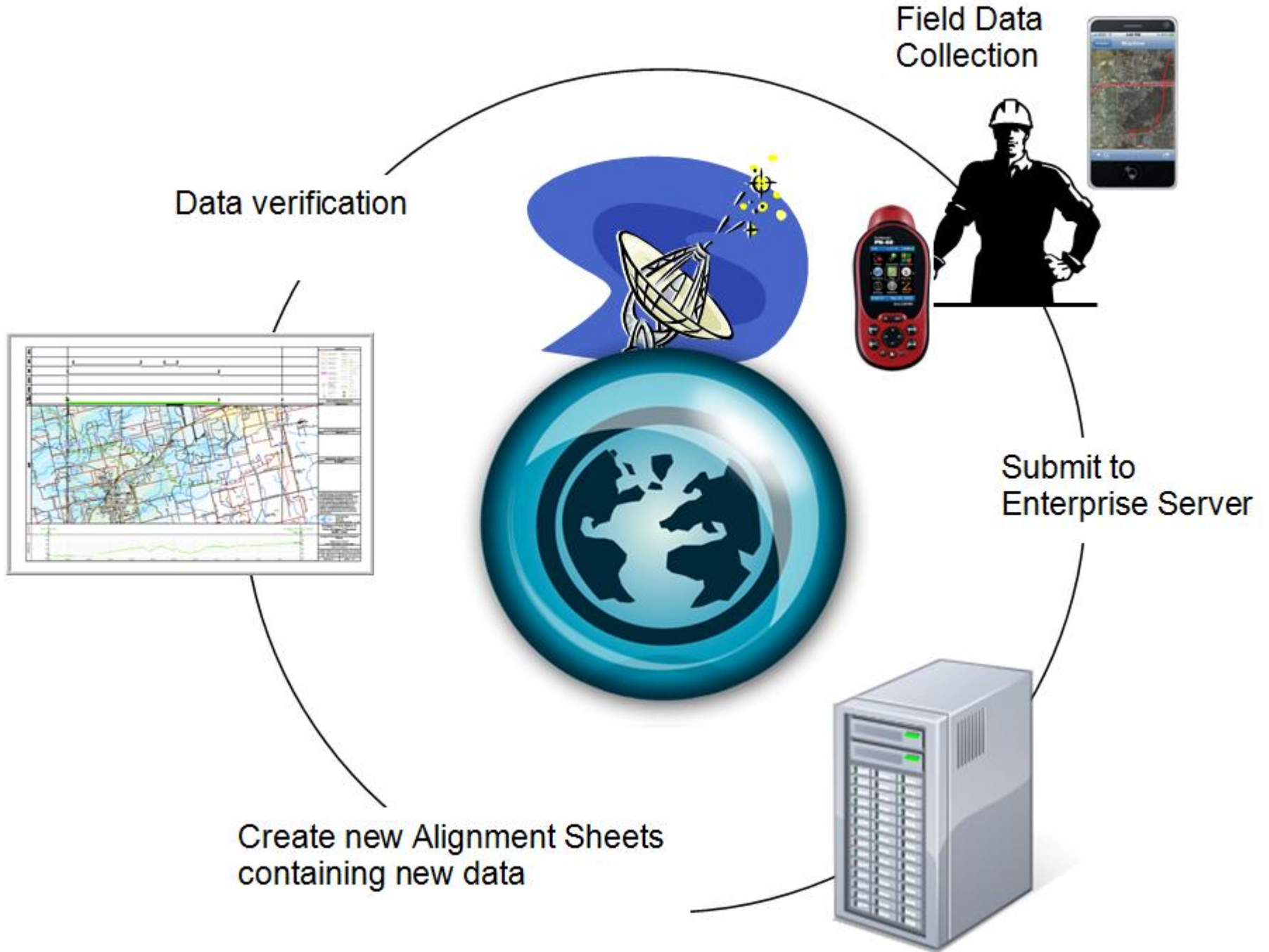
Focus of model

Vector data is focused on modeling discrete features with precise shapes and boundaries.

Raster data is focused on modeling continuous phenomena and images of the earth.

GIS data collections





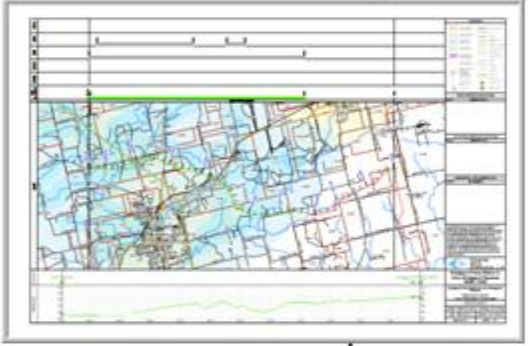
Field Data Collection



Submit to Enterprise Server



Data verification



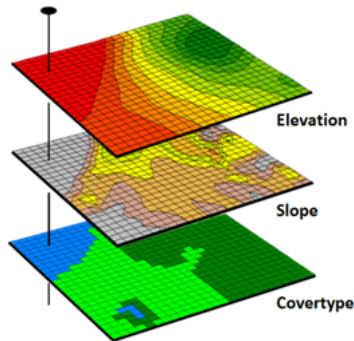
Create new Alignment Sheets containing new data

A Mathematical Structure for Spatial Analysis

Geotechnology → RS - **GIS** - GPS

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

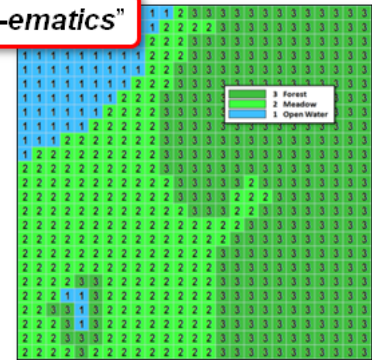
Map Analysis/Modeling



1) Maps as Quantitative Data

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

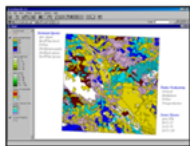
"Map-matics"



2) Spatial Analysis Operations

3) Spatial Statistics Operations

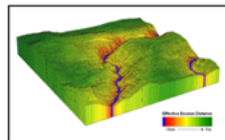
Traditional GIS



Forest Inventory Map

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

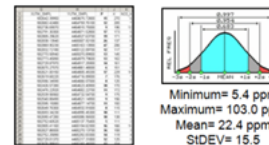
Spatial Analysis



Erosion Potential (Surface)

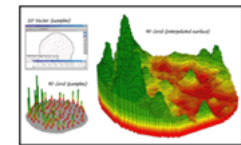
- Cells, Surfaces
- Continuous Geographic Space
- Contextual Spatial Relationships

Traditional Statistics



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

Spatial Statistics



Phosphorous Distribution (Surface)

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

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)

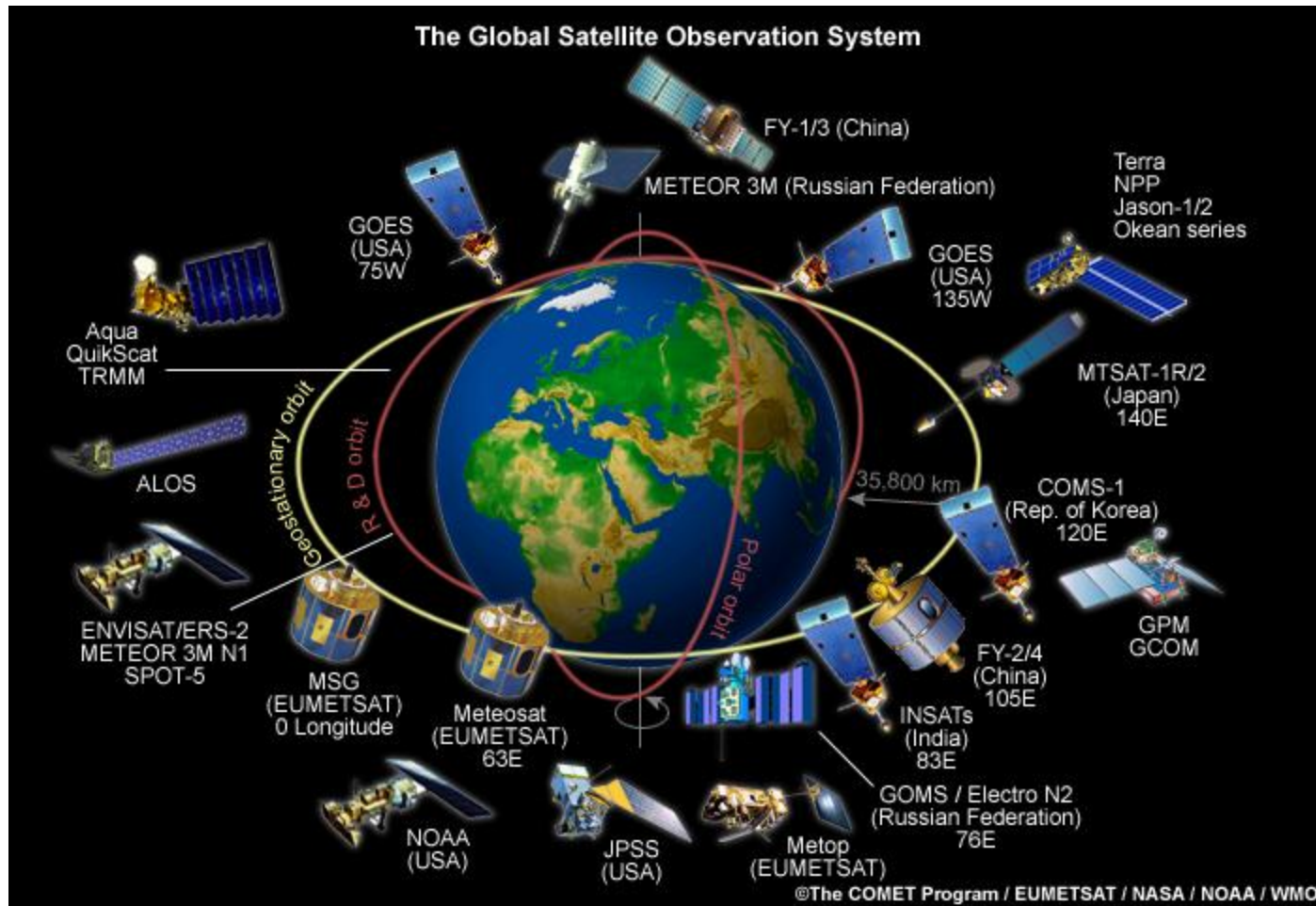
Remote sensing

- Remote sensing 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.pdf>34

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

Satellites



Satellites

Positions around the globe

Name	Abbreviation	Resolution (m)	Availability	Return Interval	Type*	Platform
Moderate-resolution Imaging Spectroradiometer	MODIS	250,500,1000	2000 to present	Daily	M	Satellite
Advanced Spaceborne Thermal Emission and Reflection Radiometer	ASTER	15,30,90	2000 to present	On demand	M	Satellite
Satellite Pour l'Observation de la Terre Vegetation	SPOT Vegetation	1150	1998 to present	daily	M	Satellite
RapidEye	RapidEye	5	2008 to present	Daily	M	Satellite
Quickbird	Quickbird	0.8,2.5	2001 to present	1 to 3.5 days	P,M	Satellite
OrbView-2	OrbView-2	1100	1997 to present	Daily	M	Satellite
Medium Resolution Imaging Spectrometer	ENVISAT-MERIS	300	2002 to present	3 days	M	Satellite
Ikonos	IKONOS	0.9,4	2001 to present	3 days	P,M	Satellite
GeoEye-1	GeoEye-1	.41,1.65	2008 to present	3 days	P,M	Satellite
FORMOSAT-2	FORMOSAT-2	2,8	2004 to present	Daily	P,M	Satellite
Color-infrared Aerial Photography	CIR	1	variable	On demand	M	Aircraft
Color Aerial Photography	Photo	1	variable	On demand	C	Aircraft
Worldview-1	Worldview-1	0.5	2007 to present	1.7 to 4.6 days	P	Satellite
Advanced Synthetic Aperature Radar	ENVISAT-ASAR	30,150,1000	2002 to present	3 days	R	Satellite
Worldview-2	Worldview-2	0.42,1.8	2009 to present	1.1 days	P,M	Satellite
Light Detection and Ranging	LIDAR	variable	variable	On demand	E	Aircraft
Unmanned Aircraft Systems	UAS, UAV	variable	variable	On demand	C,M	Aircraft
Advanced Very-High Resolution Radiometer	AVHRR	1.1km	1981 to present	twice daily	M	Satellite

*C=Color, E=Elevation, H=Hyperspectral, M=Multispectral, P=Panchromatic, R=Synthetic Aperature Radar

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.

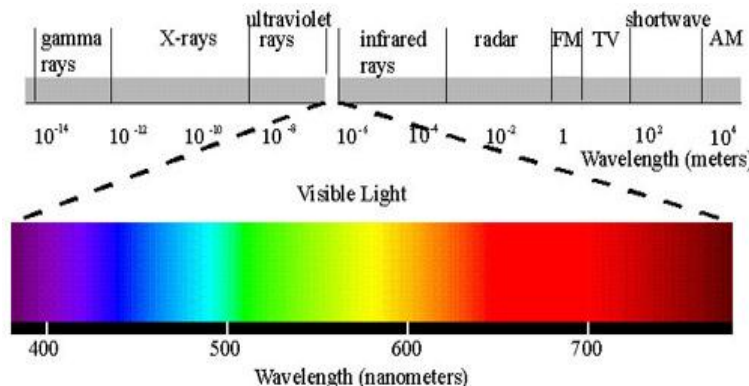
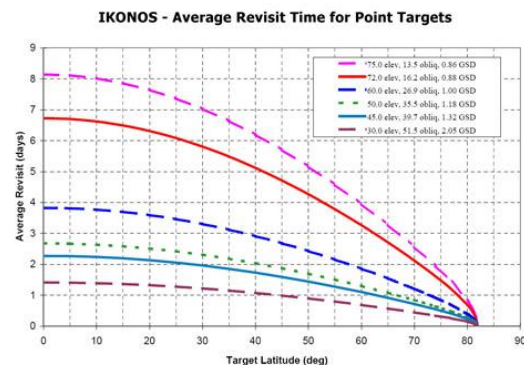
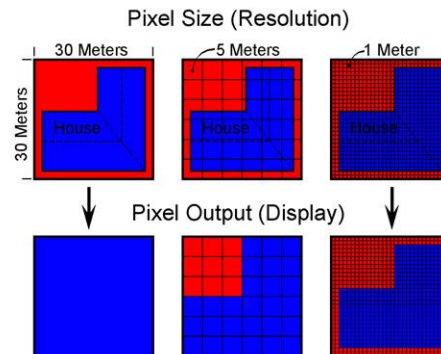
- High temporal resolution: < 24 hours - 3 days
 - Medium temporal resolution: 4 - 16 days
 - Low temporal resolution: > 16 days

- 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.

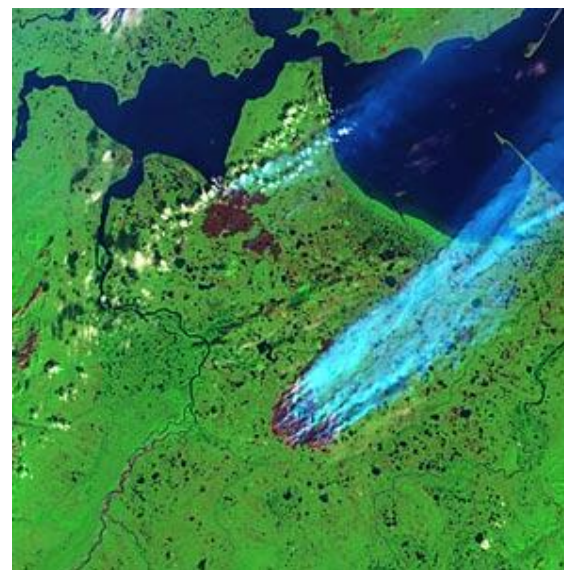
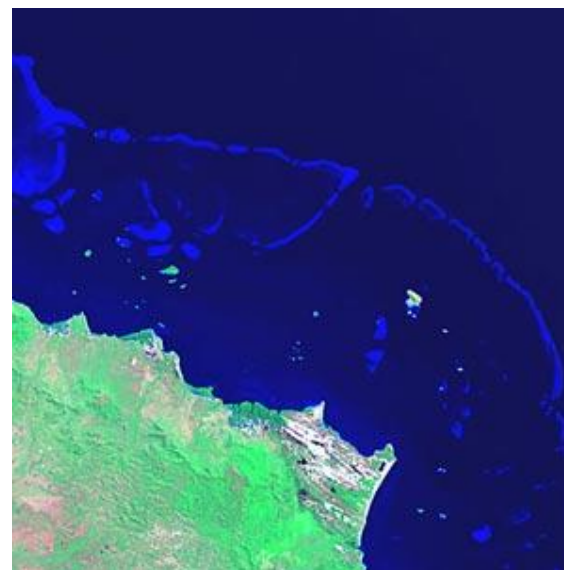
- High spectral resolution: - 220 bands
 - Medium spectral resolution: 3 - 15 bands
 - Low spectral resolution: - 3 bands

- 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).



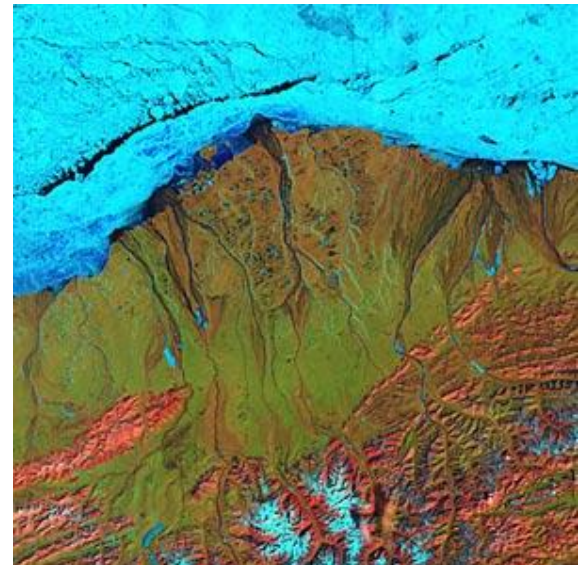
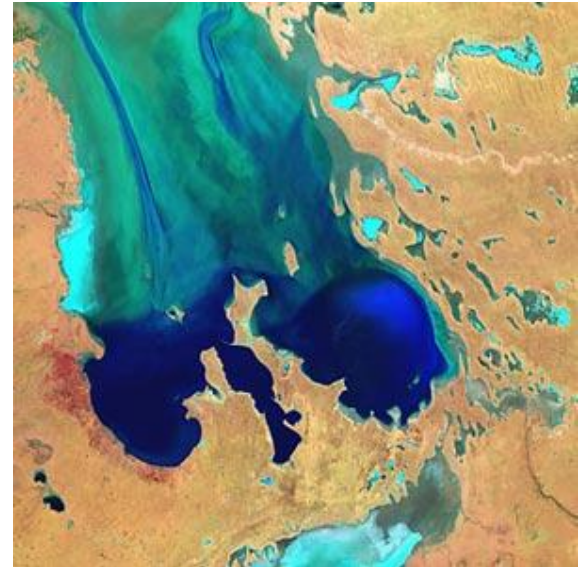
Landsat Thematic Mapper Bands and their Uses

- 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

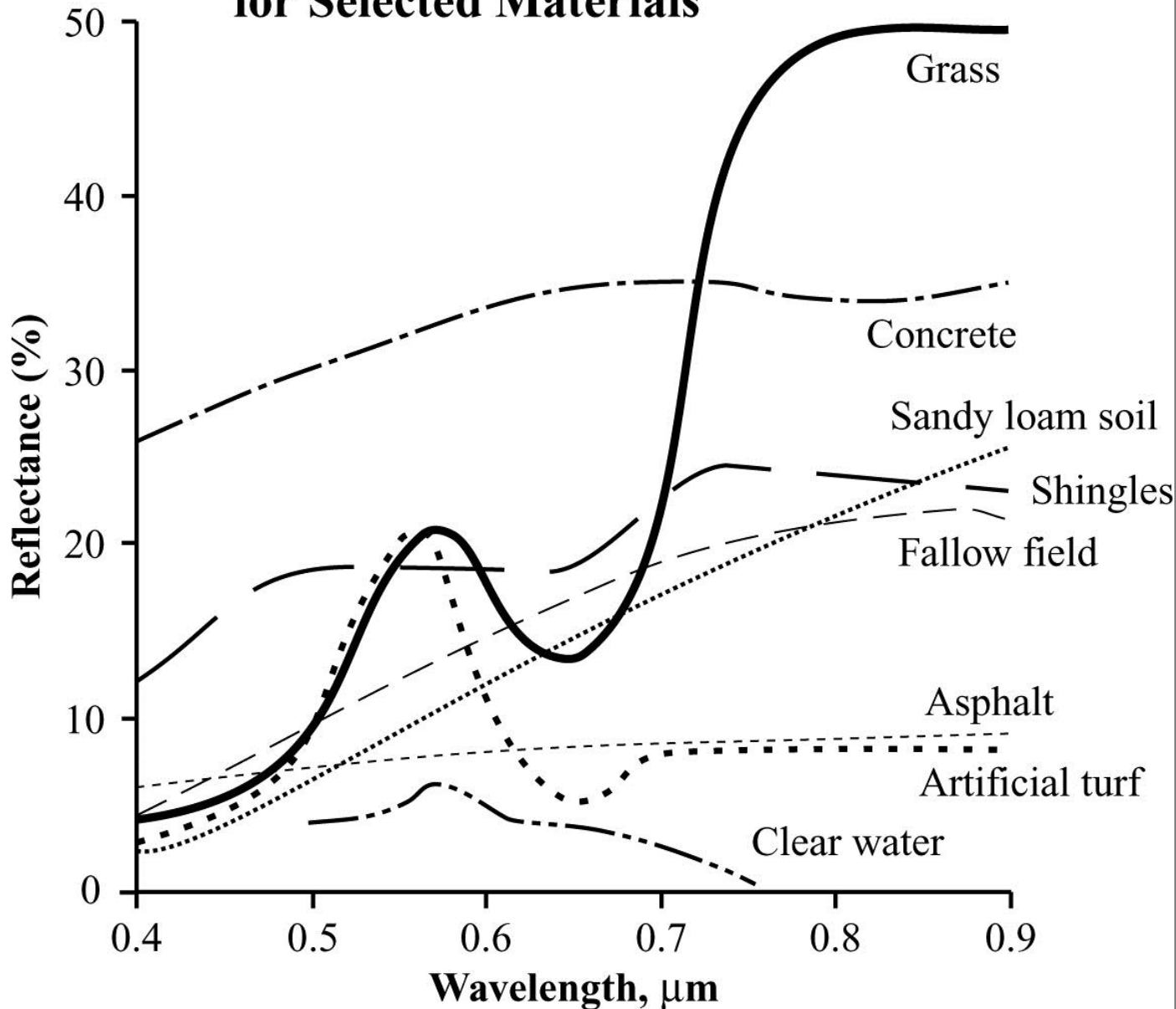


Landsat Thematic Mapper Bands and their Uses

- 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)



Spectral Reflectance Curves for Selected Materials



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

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)

- ESRI – Products include ArcView 3.x, ArcGIS, ArcSDE, ArcIMS, ArcWeb services and ArcGIS Server
- 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).
- 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.
- 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

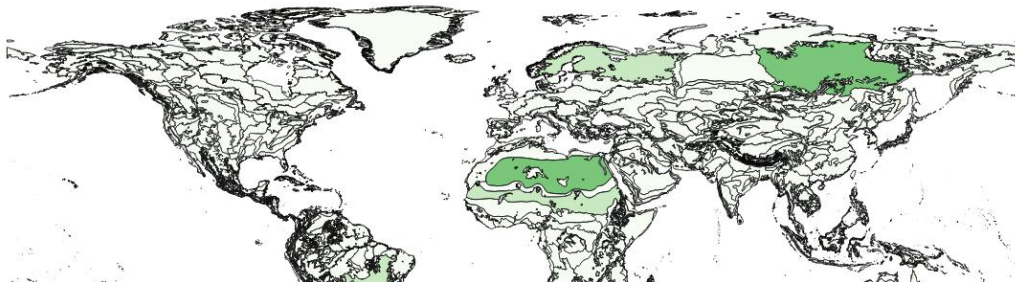
- **QGIS - A Free and Open Source Geographic Information System**
(<http://www.qgis.org/en/site/>)
- **Refer to QGIS Tutorial:**
<http://www.qgistutorials.com/en/>
- **Google Earth:**
- **A simple map with attributes for environment statistics**

Some resources and data

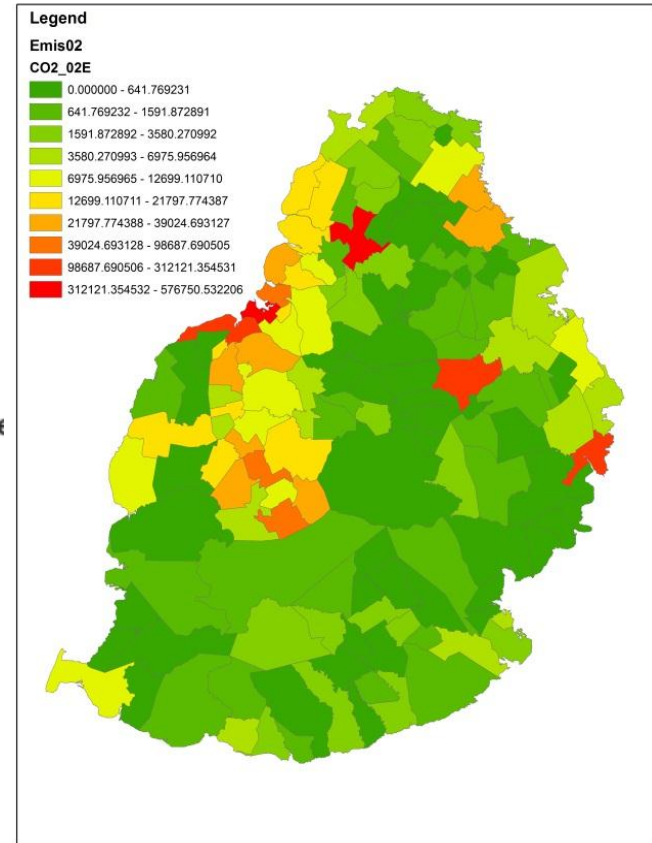
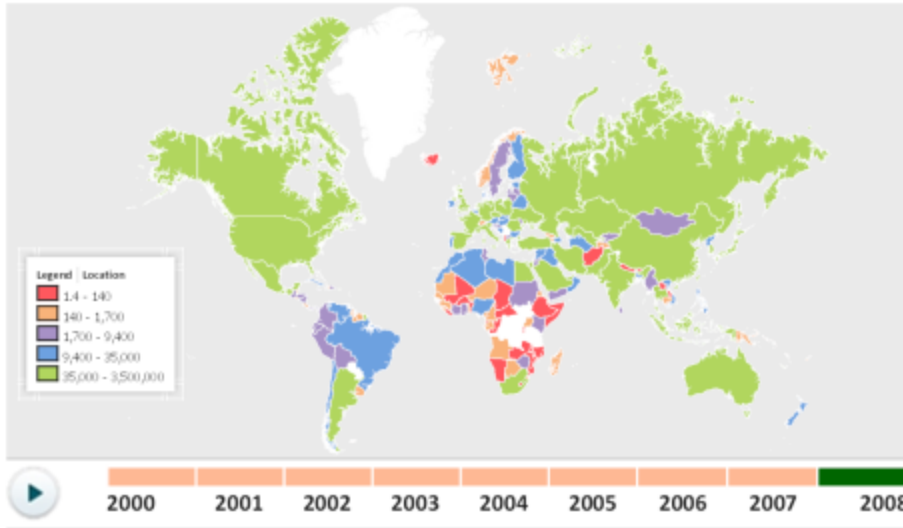
- Tutorials: http://spatial-analyst.net/wiki/index.php?title=Main_Page
- Maps, Data, Models: <http://sage.wisc.edu/mapsdatamodels.html>
- Satellite data: <https://earthdata.nasa.gov/>
- VIEWER: <http://www.esri.com/software/landsat-imagery/viewer>
- Ecol/footprints:
<http://www.arcgis.com/home/webmap/viewer.html?webmap=1a40fa5cc1ab4569b79f45444d728067>
- Data portal: <http://knoema.com/onsbcce/new-page>
- SEDAC: <http://sedac.ciesin.columbia.edu/maps/tools>
- R Software: https://github.com/Pakillo/R-GIS-tutorial/blob/master/R-GIS_tutorial.md
- Data Websites: Africa: <https://lib.stanford.edu/gis-branner-library/data-websites-africa>
- AfricaMap: <http://worldmap.harvard.edu/africamap/>
- Statistics: <http://vassarstats.net/index.html>

Examples

- World Eco regions and carbon dioxide emissions (Mauritius)



CO2 excluding short-cycle organic carbon from biomass burning - Public e



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

