Consideration of Temporal / Spatial Resolutions in Environmental Analysis

Mitsunori YOSHIMURA
Research Institute for Humanity and Nature

1. Introduction

Remote Sensing and Geographic Information System(GIS) are powerful tools for gathering , retrieving various kinds of spatial distributed informations and analyze an environmental conditions. Remote Sensing and GIS are tools not only for scientific research on how the world works, but also for technological applications in meeting human needs. The need between research and application is especially important to the emergent programs for monitoring the environmental and social consequence of global change.

The type of spatial information system required for regional to continental scale environmental analysis is huge volume (e.g., 103-106 megabyte) and may include fundamentally different kinds of data, for example, (a) multi-temporal and multi-resolution digital images acquired from one or more satellite and aircraft platforms; (b) digital maps of land surface variables such as soil, hydrography, and vegetation cover; (c) socioeconomic data (e.g., population density, zoning district) aggregated by political reporting units. Here, we consider the temporal / spatial resolutions in an environmental analysis.

2. Scaling of Earth Surface Phenomena

The earth surface phenomena appear homogeneous at one spatial scale but heterogeneous at another. The scaling properties of earth surface valuables should be known and should guide the collection, processing, and interpretation of remote sensing and GIS data. Scale dependence is especially significant in the context of GIS analysis. It seeks to reduce or to exploit relationships among geographical valuables, because those relationships change as the spatial scale changed. The scaling properties of many earth surface processes are not well known, because these properties are frequently site or region specific and also time-dependent. And it difficult to generalize from isolated studies. A key sequence of scale dependence is the presence of spatial covariability in most spatial dataset.

3. Measurement and sampling geographic phenomena

Extrapolation of point measurements and model estimates to large areas remains a major problem in geographic analysis, and continued research is needed to identify appropriate sampling and scaling strategies for sparse ground measurements, especially in the context of regional and global assessments. Interpolating point measurements to a surface creates variation that may or may not approximate the scaling properties of the actual surface.

The measurement scale of remote sensing data is relatively well specified compared to many geographic data, but may still be quite uncertain. Resolution depends instead on the complex generalization process applied by the analyst. For this reason the effective scale of GIS applied data is sometimes described in terms of the minimum mapping unit (MMU), but the actual MMU may vary both within and between maps as a function of map classes, terrain type, and analyst.

The pixel size is generally taken to define the spatial resolution of remote sensing data, although the term image resolution has various meanings. However, the measurement scale is not fixed. Resolution varies not only as a function of instantaneous field of view (IFOV) and altitude, but also because of many other factors including the sensor point spread function, surface-sensor geometry, atmospheric conditions, and data processing such as image rectification or enhancement. The earth surface processes and phenomena exhibit characteristic scale dependencies, remote sensing data of multiple resolutions, either from multiple sensors or from degradation of high resolution imagery, can be used to study and exploit those dependencies for mapping and modeling.

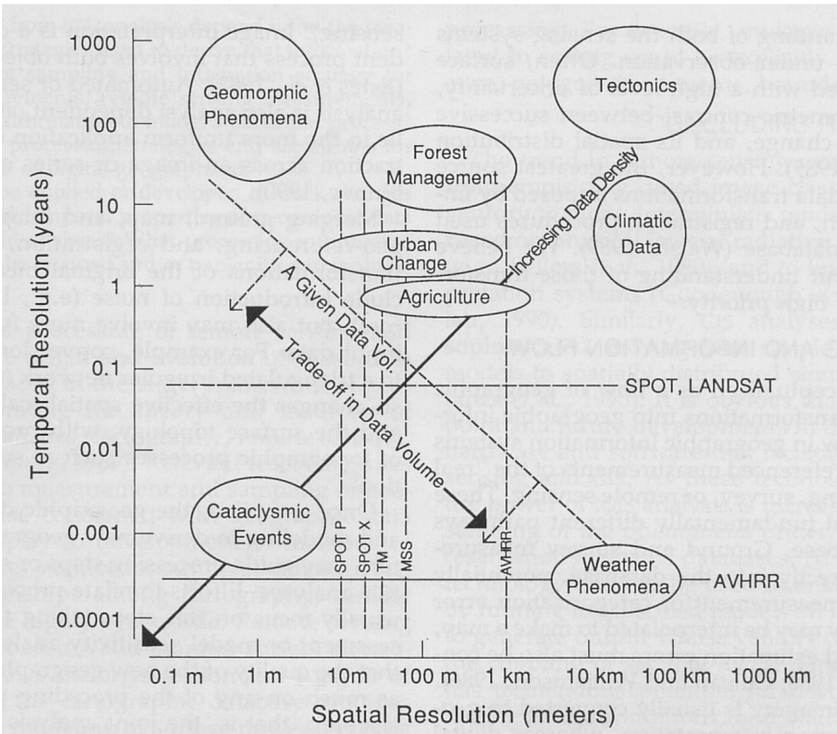

Fig. 1 Spatial and Temporal measurements scales for ground phenomena and remote sensing data.(Frank W. Davis, 1991)
Data Density decrease from lower left to upper light

Figure 1 is the spatial and temporal measurement scale for ground phenomena and remote sensing data. The data density depends jointly on spatial and temporal resolution, so that data density decrease from the lower left to upper right corners of this diagram. Increases in computing capacity have shifted the data volume threshold towards the lower left corner. There are still very real practical limits to the spatial and temporal domain of remote sensing for regional and global analysis, and do the volume of data that can be effective archived, retrieved and analyzed. For global analysis, practical scales are still far more coarse than the measurement scales of many kinds of biophysical data. A challenge in combining remote sensing and GIS for Earth science studies is the proper nesting of observations at mulyiple space and time scale in order to link short-term, fine scale measurements and process models to long-term, broad scale measurement and modeling efforts.

4. Monitoring and Change Detection

Although satellite remote sensing has been used for monitoring earth surface processes through time, there has been remarkably little progress in quantitative spatiotemporal analysis of multi-temporal imagery for land surface analysis. There is a pressing need for such research applied to sensors with low spatial resolution and short repeat intervals as part of efforts to study global ecological changes.

There are many uncertainties in detecting change using multi-temporal satellite data. The ability to detect changes in a surface identified over time with remote sensing depends on the spatial, spectral, radiometric and temporal properties of sensor system. High frequency variation in solar, atmospheric and surface conditions during scene acquisition contribute noise to the analysis.

5. Thematic Information Extraction

The sensor systems and spatial resolutions useful for discriminating vegetation from a global to an in site perspective are summarized in Fig.2. This suggests that the level of detail in the desired classification system dictates the spatial resolution of remote sensing data. Spectral resolution is also an important consideration. However it is not as critical a parameter as spatial resolution since most of sensor systems record energy in approximately the same visible and near-infrared portions of the electromagnetic spectrum

The Level I is the global scale. Its typical satellite remote sensing data is NOAA/AVHRR with 1.1km resolution.

The Level II is second spatial level. It is continental. Used satellite data spatial resolution is from 80m to 1.1km. NOAA/AVHRR and Landsat MSS are typical sensors.

The Level III is Biome with 30m to 80m resolution. Landsat TM and MSS are the sensors.

The Level IV corresponds to the region scale with 3m to 30m resolution. Landsat TM and also IKONOS Multi-spectral as high resolution satellite data.

The Level V is Plot. This scale corresponds to high resolution satellite data at this moment. It is IKONOS or Quick Bird.

The Level VI is the most detailed spatial scale. It is In Site sample Site. At this level, all of phenomena can observed by direct surface measurements and observations

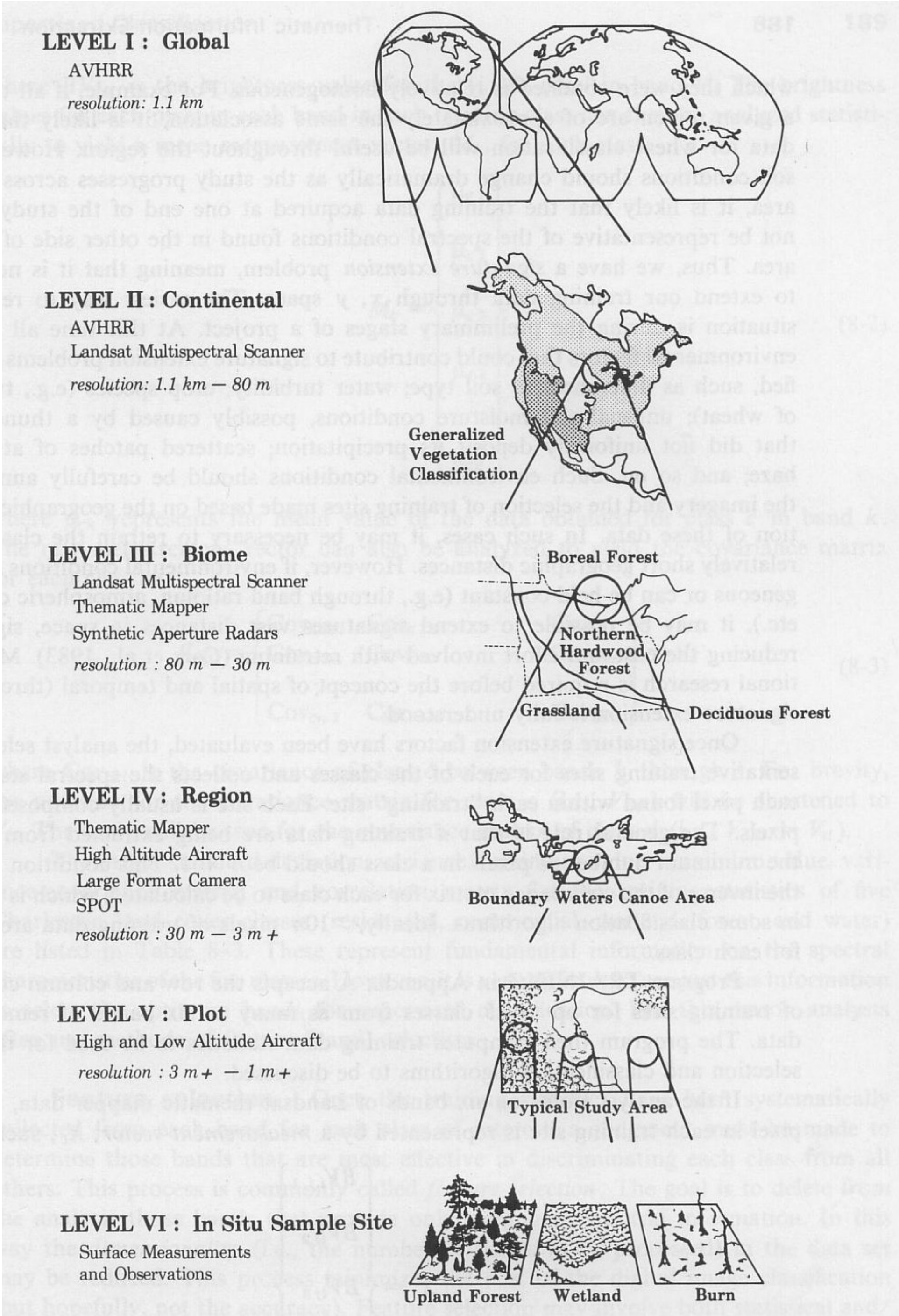

Fig. 2 Relationship between the Level of detail required and the Spatial Resolution of Various Remote Sensing Systems for Vegetation Inventories.
(From NASA, 1983;Botkin et al.,1984)