GIS and Remote Sensing

Image data availability and incorporation into GIS

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Spatial data retrieval

- Remote sensing measurements of surface characteristics
  - surface hydrology
  - soil-vegetation-atmosphere transfer
- large area assessment
  - spatial data
  - temporal repetition

Overview

- data use in hydrological applications
- satellite systems
- image processing example
- software and data exchange
- new developments

Parameter retrieval for Hydrology

State variables

- surface temperature
- surface soil moisture

Other spatial data

- land use categories
- vegetation biomass
- surface roughness
- DEM

Secondary parameters

- regions of varying ET
- ground water recharge and discharge zones
- storm runoff contribution
- hydrologic properties of soils
- spatial pollution

Available remote sensing systems I

Optical scanners spectrometers and altimeters

Sensor	System	Global Coverage	Spatial Resolution	Temporal Resolution [days]	Frequency/Wavelength	Parameter examples
LANDSAT-TM	multi-spectral scanner	y	30m	17	450 – 520 nm 520 – 600 nm 630 – 690 nm 760 – 900 nm 1550 – 1740 nm 10400 – 12500 nm 2080 – 2350 nm	land use NDVI, LAI, biomass http://geo.arc.nasa.gov/sge/landsat/landsat.html
SPOT HRV XS	multispectral and panchromatic scanner	y	5m PAN 10m XS	26	500 – 590 nm 610 – 680 nm 790 – 890 nm	DEM from stereoscopic data land use plant parameters http://www.spot.com
IRC-1C	LISS-3 WIFS	y	23m, 70m 188m	24	520 - 590 nm 620 - 680 nm 770 - 860 nm 1550 - 1700 nm WIFS: 620 – 680 nm 770-860	land use NDVI, LAI, biomass http://www.euromap.de/doc_004.htm
NOAA/AVHRR	advanced very high resolution radiometer	y	1.1km	12	580 - 680 nm 725 - 1100 nm 3550 - 3930 nm 10300 - 11300 nm 11500 - 12500 nm	NDVI clouds http://www.ncdc.noaa.gov/ol/satellite/satelliteresources.html
Earth Probe/TOMS	total ozone imaging spectrometer	y	39km x 39km	1	360.0 nm 331.2 nm 322.3 nm 317.5 nm 312.5 nm 308.6 nm	aerosol, ozone, UV Radiation, atmospheric chemistry http://jwocky.gsfc.nasa.gov/index.html
GOES	imaging spectrometer	y	1 km	2	550 - 750 nm 3800 - 4000 nm 6500 - 7000 nm 10200 - 11200 nm 11500 - 12500 nm	clouds, rainfall rates http://www5.ncdc.noaa.gov/plwebapps/plsql/goesbrowser.goesbrowsemain
TOPEX/ Poseidon	2 Altimeters	+/- 60°	1.6 - 3 km (ALT) 7 km (SSALT)	10	ALT: 13.6 GHz SSALT: 16.6 GHz	sea surface altimetry river and lake level altimetry http://www-ccar.colorado.edu/researc

Available remote sensing systems II

Sensor	System	Global Coverage	Spatial Resolution	Temporal Resolution [days]	Frequency/Wavelength	Parameter examples and web-page
SSM/I	Radiometer	y	70 x 45 60 x 40 38 x 30 16 x 14	1	19.35 GHz, HV 22.24 GHz, V 37.00 GHz, HV 85.50 GHz, HV	soil moisture snow cover sea ice ocean surface wind speed http://www.ncdc.noaa.gov/ol/satellite/ssmi/ssmiproducts.html
ERS-2 ATSR	along track scanning radiometer: MW sounder and IR Radiometer	y	20 km 1 km	3	MW Sounder: 23.8 GHz 36.5 GHz IRR: 1600 nm 3700 nm 11000 nm 12000 nm	atmospheric water vapor, liquid water, sea state, sea surface temperature http://www.esa.esrin.it
ERS-2 RA	radar altimeter	mostly oceans	16 – 20 km	3	330 MHz Ocean 82.5 MHz Ice	ocean level ice, sea ice level http://www.esa.esrin.it
ERS-2 AMI-SAR	Windscatterometer mode	y	50 km	17	5.3 GHz, VV	wind speed, ocean waves, sea ice
RADARSAT	Scan SAR mode	y	e.g. 50 x 50 m	24	5.3 GHz, VV	wind speed, ocean waves, sea ice http://radarsat.space.gc.ca

Future remote sensing systems

Sensor	System	Global Coverage	Spatial Resolution	Temporal Resolution [days]	Frequency/Wavelength	Parameter examples
SRTM (1999)	Shuttle Radar Topography Mission	y	5°x 5°	a 10 day period	5.3 GHz	DEM, surface roughness http://www-radar.jpl.nasa.gov/srtm/
ENVISAT A-SAR (2000)	Advanced Synthetic Aperture Radar	y	30 – 75m	< 17	5.3 GHz, VV	surface roughness snow water equivalent freeze/thaw cycles http://envisat.estec.esa.nl/
EOS MODIS (2000)	Spectrometer	y	0.25 km 0.5 km 1 km	1-2	app. 19 optical channels	land surface temperat. land/cloud boundaries land/cloud properties atmosph. water vapor http://ltpwww.gsfc.nasa.gov/MODIS/MODIS.html http://ltpwww.gsfc.nasa.gov/MODIS/MAS/index.html
EOS ASTER (2000)	Advance Space-borne Thermal Emission and Reflection Radiometer	y	15 m VIS 30 m SWIR 90 m TIR	16	app. 14 optical channels	evaporation vegetation stress soil moisture http://eos-am.gsfc.nasa.gov/aster.html
EOS MISR (2000)	Multi-angle Imaging Spectro-radiometer	y	0.275 km	9	443 nm 555 nm 670 nm 865 nm	vegetation parameters vegetation indices http://eos-am.gsfc.nasa.gov/misr.html

Future radar systems

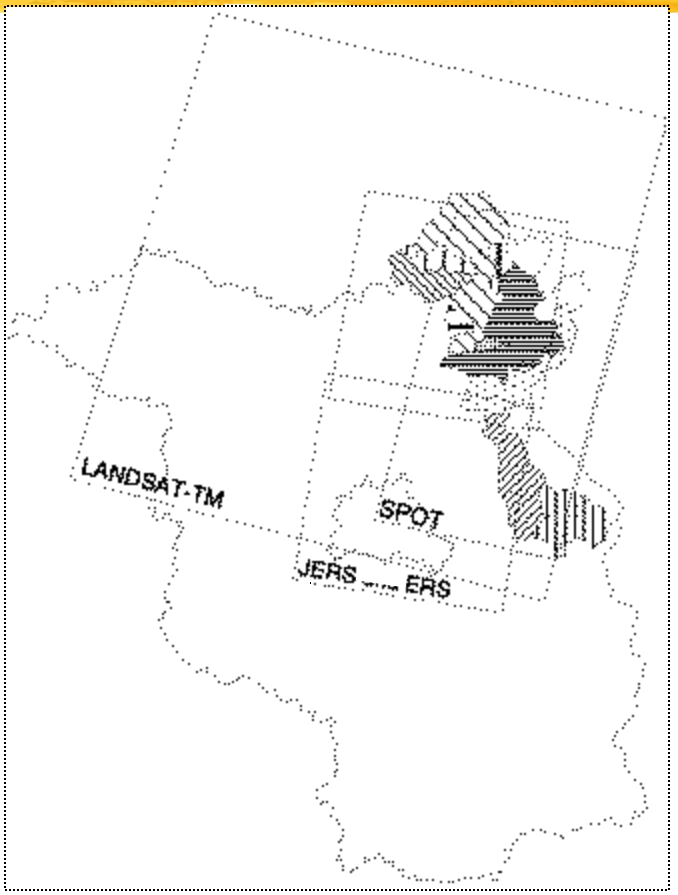
Sensor	Frequency	Provider	Program	Launch	web-page
Radarsat I and II	Cvv, Chv	CCRS	RADARSAT		http://radarsat.space.gc.ca
AMSR Adeos II	Cv	NASA	EOS-PM	2000	http://lightsar.jpl.nasa.gov/
ASAR	Cv	ESA	ENVISAT	2000	http://envisat.estec.esa.nl/instruments/asar
Lightsar	L-band polarimetric	NASA/JPL	Lightsar	2002/2003	http://lightsar.jpl.nasa.gov/
SMOS	Lhv 2-d	ESA	Living Planet (?)	2002-2004	?
CMIS	Chv	US Weather	Polar Orbiter	2007	?

Data exchange with GIS

- decision for raster or vector GIS or hybrid systems
- data quantization and volume
- full exchange of geometry (e.g. regions) and attribute table?
- handling of complex data formats (HDF, CDF)?

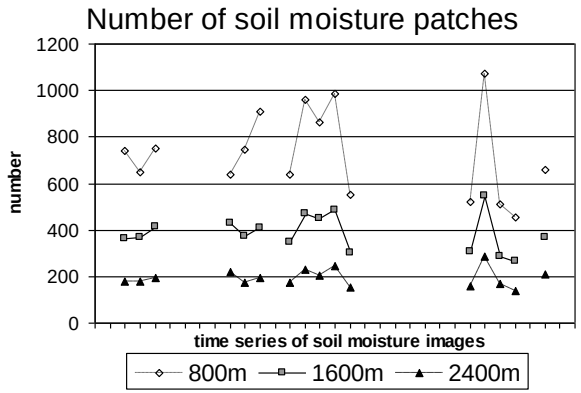
Spatial data resolution problem

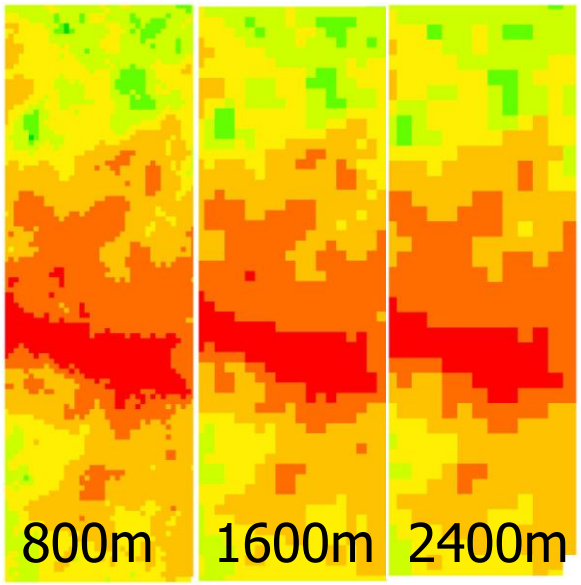
- trade-off pixel size vs. spatial coverage
- quantization and data volume
- data merge from different sources
- grid displacement in time
- information content of different resolutions
- raster-vector conversion



Information loss & pixel resolution

- spatial statistics to analyze information loss
- see poster P1.8





- Fragstats for raster data (free)
- Fragstats for vector data by Innovative GIS Inc, Fort Collins, CO

www.innovativegis.com

FRAGSTATS * ARC

Image processing software and portability of formats

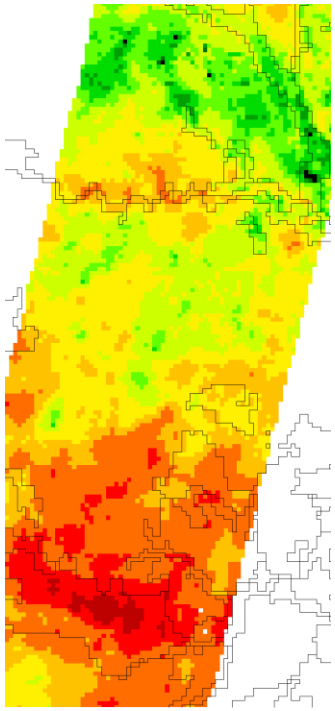
- ARC/Info GRID — various basic raster formats, tif, sun, gis, lan, img, bil, bip, bsq, grass, adrg, rlc
- Arcview — ERDAS lan, img, grid, tif
- ERDAS IMAGINE — Arc/info live link, no conversion needed
- PCI EASI PACE — Arc/Info GeoGateway for multiple formats
- ENVI/IDL — imports shapefiles, e00, dxf, USGS, SDTS, dlg, exports ArcView grid, uses own vector format
- ERMAPPER — various raster formats, import of dxf and SeisWorks, uses own vector format
- other packages: TNT, IDRISI, ILWIS...

Image processing steps

- geometric and radiometric correction
- atmospheric correction
- subsetting, mosaic, enhancement
- geo-coding (map projection, spheroid, units)
- parameter extraction (multivariate statistics, regression model, physical model etc.)
- post-processing (filtering, grouping, data reduction)
- Raster GIS: focal or global operations
- hybrid GIS: zonal/region-based operations, spatial statistics

Raster data or hybrid GIS analysis

- Global or focal analysis
  - find contiguous pixels
  - eliminate data by area
  - search for raster layer combinations
  - define rules for overlay analysis
  - pixel comparisons between images

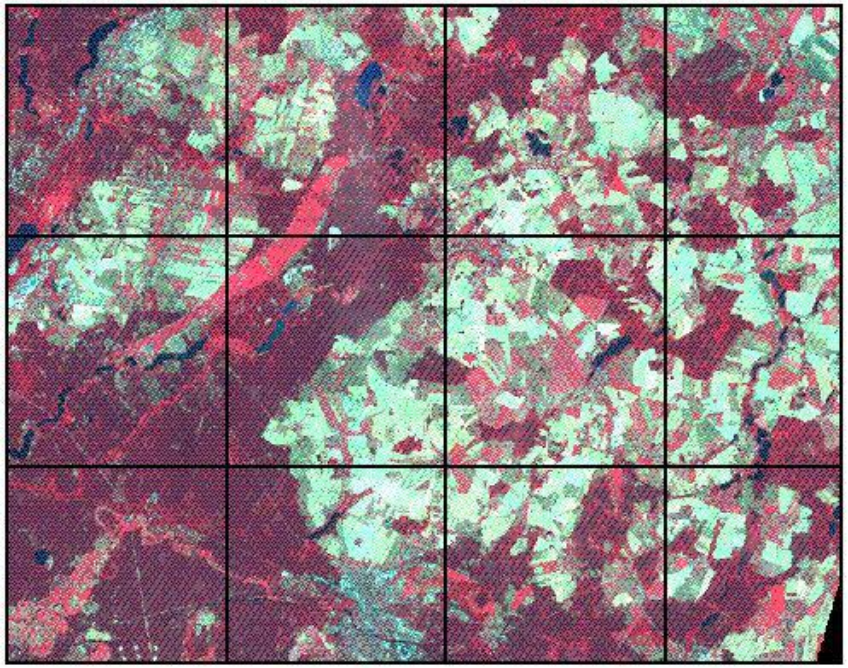


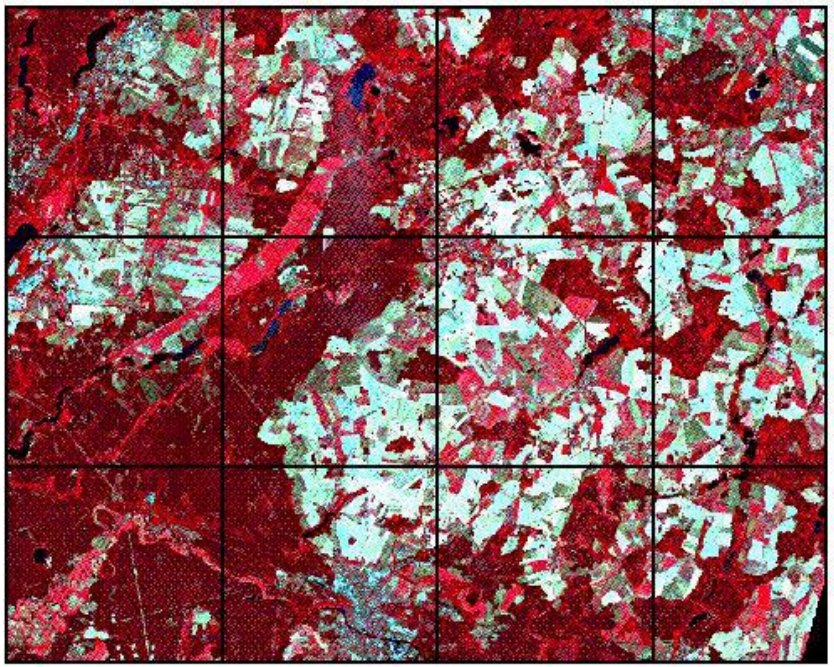
Soil moisture
and
soil texture overlay

- zonal operations
  - spatial statistics in defined polygon overlays
  - descriptives, diversity, proximity, neighborhood etc.

Atmospheric Correction

- LANDSAT-TM without and with atmospheric correction

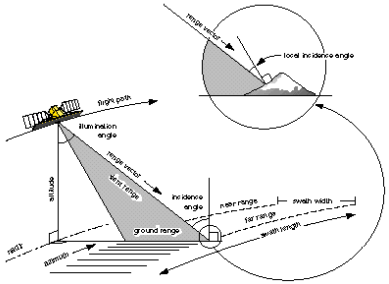




Soil moisture retrieval from SAR

Image processing steps

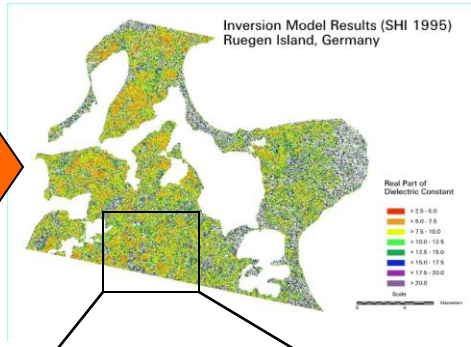
- slant range correction
- speckle reduction (multi-looking)
- inversion modeling (physical model) to obtain soil dielectric constant ε
- conversion of ε into %Vol with 3rd order polynomial (e.g. Topp et al. 1991)
- grouping into 5% classes
- raster-to-vector conversion or raster use in GIS

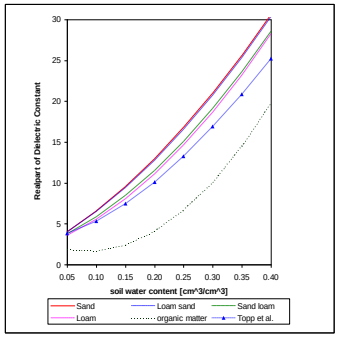


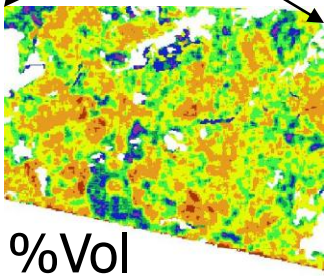
Inversion Model Dubois et al. (1995)

$$\sigma^{\circ}_{hh} = A\,\frac{\cos\theta^{1.5}}{\sin\theta^{5}}\,10^{0.28\varepsilon\tan\theta}\,(kh\sin\theta)^{1.4}$$

$$\sigma^{\circ}_{vv} = \frac{\cos\theta^{3}}{\sin\theta^{3}}\,10^{0.46\varepsilon\tan\theta}\,(kh\sin\theta)^{1.1}$$







%Vol

Processing level of remote sensing data

- raw data from the satellite
- system corrected, calibrated, geo-coded, terrain corrected
- atmospheric correction for optical data
- thematic evaluations (land use, NDVI, rainfall etc.)
- EXA-Byte tape, CD-ROM
- most commercial data formats are read by software
- generic binary format BSQ, BIL

Data providers

- EROS Data Center, edcwww.cr.usgs.gov
- RADARSAT Int., www.rsi.ca
- EOSAT, www.eosat.com
- ESA/ESRIN, www.esrin.esa.it
- EURIMAGE, www.eurimage.com
- NCDC, www2.ncdc.noaa.gov:80
- ...

3-D Visualization and analysis

- ERDAS IMAGINE Virtual GIS, www.erdas.com
- ESRI ArcView 3D Analyst, www.esri.com
- CLR PolyTRIM Polygonal Toolkit for Representation, Interaction and Modelling, www.clr.utoronto.ca/POLYTRIM/polytrim.html
- Wooleysoft Visual Explorer 98 www.woolleysoft.co.uk/main.html
- CIRAD AMAP Advanced Modeler of the Architecture of Plants for SGI, GrowthEngine, Texture, Terrain, Landmaker, Animation, www.cirad.fr/logiciels/amap/amap.html
- TerraVision Artificial Intelligence Center, www.atsi.com/indexprod.html
- INTERGRAPH MGE Terrain Modeler, MGE Geologic Analyst, MGE Kriging Modeler, MGE Voxel Analyst, MGE ModelView, www.intergraph.com/iss/products/mapping/gis/msm.htm
- Questar Productions World Construction Set, www.questarproductions.com
- ERMapper, www.ermapper.com
- Konrad Zuse Center for Informationtechnology Berlin Amira, www.zib.de

Summary

- Remote sensing data provide large area spatial data for GIS analysis and modeling
- basic thematic products are available
- image processing and model coupling is often needed to retrieve quantitative data
- commercial software for combined evaluation is widely available
- data merge should be done carefully