ESRS Training Courses for Professional Scientists

Cutting edge scientific techniques for a dynamic future

Presented by:

ESRS
Earth Science Remote Sensing Lab

http://www.esrs.wmich.edu/training/

Description:

The *Remote Sensing for Professional Scientists* program is designed by remote sensing professionals with decades of cumulative experience working both in academics and private consulting. The ESRS team of professionals draws from an international and interdisciplinary pool or talent.

The program is designed to prepare its participant for applying advanced remote sensing processing and interpretation to earth science applications with emphasis on environmental and hydrogeologic applications. The program incorporates training on modern remote sensing technologies, analysis of satellite images and advanced sensors, and integration of remotely acquired observations with observations extracted from other traditional data sets/disciplines including geochemistry, geophysics, hydrology, modeling, and advanced data organization techniques.

Participants completing the offered training programs will be fully prepared to apply the acquired skills to a multitude of dynamic scientific applications and real world environmental problems. In a rapidly evolving scientific world the difference between the success and failure of any scientific endeavor is no longer the availability of data, but the understanding of how to extract, integrate, and analyze the overwhelming body of data readily available.

Lead Instructors:

Dr. Mohamed Sultan (PhD)

Dr. Mohamed Ahmed (PhD)

Dr. Neil Sturchio (PhD)

Dr. Eugene Yan (PhD)

ESRS Staff

Upon completion of the training program, the participant will receive a certificate from the ESRS indicating the satisfactory completion of the training modules at a state of the art facility under leading professionals in the field.

Table of Contents

I. Training Schedule

1) Geologic & Environmental Remote Sensing

Full course: 4 weeks; Short course: 2 weeks

a. History and Scope of Remote Sensing
b. Electromagnetic Radiations
c. Spectroscopy of Rocks and Minerals & Principles
d. Multispectral and Hyper-spectral Remote Sensing
e. Active Microwave and LIDAR
f. Thermal Infrared Radiation

2) Remote Sensing, Digital Image Processing & Applications in Hydrogeology

Full course: 4 weeks; Short course: 2 weeks

***** <u>Hands-on applications using ENVI & GIS software applications</u>

a. Using ArcGIS to explore groundwater in arid environments
b. Large-scale correlations from space-borne observations
c. Introduction to hand-held spectrophotometer
d. Compositional and structural mapping with Landsat TM data
e. Paleoclimatic inferences from SIR-C data

3) Hydrogeology Field Course (6 weeks)

Each unit is 1 week; Students can take as many units as needed

a. Hazardous Waste Operations and Emergency Response (HAZWOPER)
b. Environmental Surface Geophysics
c. Principles of Well Drilling and Installation
d. Principles and Practices of Ground-water Sampling and Monitoring
e. Principles and Practices of Aquifer Testing
f. Remediation Design and Implementation
g. Assessment of renewable water resources

4) Continuous Rainfall-Runoff Modeling using SWAT

Full course: 4 weeks; Short course: 2 weeks

a. Principles of Hydrologic Models
b. Introduction to Rainfall-Runoff Models
c. Introduction to Modeling Inputs and Databases
d. Soil Water and Assessment Tool Model Setup & Simulation
e. Sensitivity Analysis & Calibration of Hydrologic Models

5) Groundwater Modeling using MODFLOW

Full course: 4 weeks; Short course: 2 weeks

- **a.** Principles of Groundwater Models
- **b.** Introduction to Modeling Inputs and Databases
- **c.** Introduction to MODFLOW
- **d.** GMS & Visual MODFLOW Preprocessors
- **e.** Sensitivity Analysis & Calibration of Hydrologic Models

6) Geographic Information Systems (GIS) & Applications in Hydrogeology

Full course: 4 weeks; Short course: 2 weeks

- **a.** Introduction to ArcGIS
- **b.** Understanding coordinate systems and projections
- **c.** Working with different data types (Vector, Raster)
- **d.** Methods in Spatial Interpolation
- **e.** Introduction to Web-based ArcGIS

7) Application of Geochemistry in Hydrogeology

Full course: 3 weeks; Short course: 2 weeks

- **a.** Hydrology
- **b.** Geochemistry
- **c.** Isotopic Analysis

8) Computer Science Applications in Hydrogeology

Full course: 2 weeks; Short course: 1 week

- a. Introduction and construction of a web based GIS
- b. Introduction to computer sciences concepts
- c. Digital image processing (RESDEM)

9) GRACE: A Tool for Monitoring Hydrogeology

Full course: 4 weeks; Short course: 2 weeks

- a. GRACE basics
- b. Processing of GRACE data
- c. Hydrologic applications of GRACE data

10) Radar interferometry: A Tool for Environmental and Hydrogeologic Applications

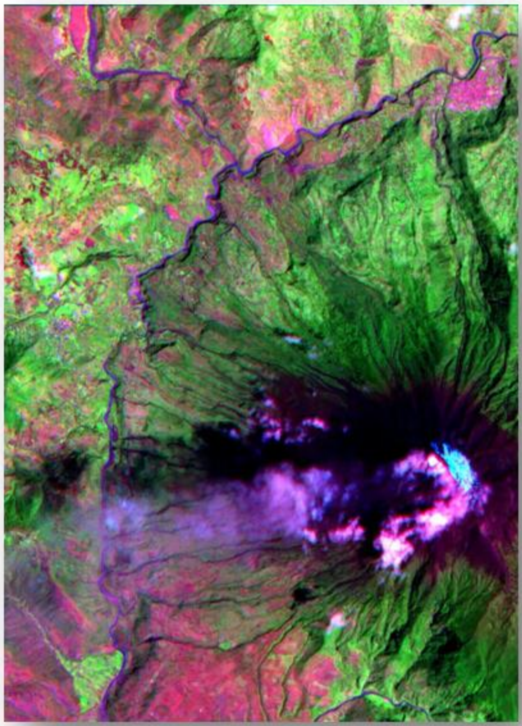
Full course: 4 weeks; Short course: 2 weeks

- a. Basics of radar interferometry
- b. Nile Delta Subsidence
- c. Landslides in Saudi Arabia

11) Applications of Remote Sensing in Aquatic Environmental Sciences
Full course: 2 weeks; Short course: 1 week

a. Basics of aquatic remote sensing
b. Detection of algal blooms using visible near infrared (VNIR)
c. Detection of thermal plumes using thermal infrared data
d. Detection of oil spills using radar applications

II. Course Description



Geologic & Environmental Remote Sensing Course

Part I - Fundamentals, data sources, and image acquisition

History and scope of remote sensing: Concepts of remote sensing, geophysical remote sensing, and milestones.

Electromagnetic radiations: Wave model of electromagnetic energy, matter interaction with atmosphere, matter interaction with terrain, radiance and hemispherical reflectance, absorbance, and transmittance.

Spectroscopy of rocks and minerals and principles of spectroscopy**:** Causes of absorption, electronic processes, vibrational processes, spectra of miscellaneous minerals and rocks, and scattering processes.

Multispectral and hyperspectral remote sensing: Landsat System, Spot, ASTER, IKONOS, AVHRR, SeaWifs, MISR, and Hyperion.

Active Microwave and Lidar: Geometry of radar images, wavelength, penetration, polarization, SAR, RADARSAT, radar interferometry, LIDAR sensor system, and canopy penetration

Thermal infrared radiation: Thermal infrared radiation properties, thermal radiation laws, and thermal properties of a terrain.

Textbooks:

Campbell, J., 2002, Introduction to Remote Sensing, Third Edition, Guilford Press, New York, 620 pp. (required)

Jensen, J.R., Remote Sensing of the Environment, Prentice Hall, New Jersey, 544 pp., (optional)

Jensen, J.R., 1996, Introductory Digital Image Processing, a Remote Sensing Perspective, Second Edition, Prentice Hall, New Jersey, 318 pp. (optional)

Remote Sensing & Image Processing Applications in Hydrogeology

Course description

The course provides extensive hands-on training on real-world geologic, hydrogeologic, and environmental projects and data sets. These data sets were collected by the instructor and his research associates over the past two decades. Throughout the course, the participants receive rigorous hands-on training on digital image processing techniques (e.g., image enhancement, classification, change detection, etc.) as well. The students learn how to extract and integrate lithologic and environmental information from a wide range of archival remote sensing data (e.g., Aerial photographs, CORONA, Landsat MSS, TM, SPOT, IKONOS, SIR-C, RADARSAT), real-time remote sensing data (e.g., NOAA, SeaWIFS [UB's receiving station]), digital elevation models, and maps (geologic, land use, land cover, etc.).

Part I – Analysis of remote sensing data

Radiometric and geometric enhancement: histogram, contrast modification, piecewise linear contrast modification, histogram matching, image smoothing, mean value smoothing, edge detection and enhancement, line detection, shape detection.

***Image classifications*:** Supervised (e.g., maximum likelihood, minimum distance classification, thresholds, parallelepiped) and unsupervised classifications (e.g., delineation of spectral classes, single pass clustering, and clustering by histogram peak selection).

Accuracy assessment: Sources of errors, and measurement of map accuracy.

Part II – Applications

Earth sciences: lithology, structure (faults, folds, suture zones), and plate reconstructions.

Environmental: land use and land cover change, monitoring sea-shore line erosion, urbanization, fires, and deforestation.

Survey: digital terrain models.

Hydrology: applications of remote sensing in surface runoff modeling and ground water flow modeling

Hands on Projects conducted in the lab throughout the course:

(1) Lithologic mapping using remote sensing data in arid lands

The students use Landsat Thematic Mapper data, Landsat Multispectral scanner data, and ASTER data together with field, petrographic, geochemical, and hemispherical reflectance data to generate a lithologic map for a 600 km^2 area in the Red Sea Hills.

(2) Structural mapping of faults, folds, and suture zones from remote sensing data

The students use the spatial distribution of rock units and their lithologic characteristics (inferred from remote sensing data) together with field and geologic data to produce a regional structural map showing the distribution of suture zones, transcurrent fault systems, and folds.

(3) Paleo-reconstructions of continental plates

The students investigate pre-Red Sea reconstructions by generating regional mosaics for the Red Sea coastlines and by correlating the lithologies and structures cropping along the Red Sea coastlines. The students determine the optimum reconstruction of the plates prior to the Red Sea opening some twenty million years ago by rotating (in spherical coordinates) one of the plates around a pole that aligns the structural and lithologic elements on either side of the Red Sea.

(4) Development of digital terrain models

The students will generate a regional digital terrain model (DEM) from a data collection of twenty pairs of stereo ASTER scenes over Libya. They will then extract stream networks and watershed distribution over the entire Libyan territory using the generated DEMS and the available DEMs (e.g., SRTM-derived DEM) for the remaining parts of Libya.

(5) Extraction and analysis of temporal precipitation and mass variation data from global remote sensing data sets over hydrologic systems of interest.

A common difficulty facing many of the hydrogeologists working in arid lands is the paucity of temporal field data (e.g., rain gauge, stream flow, head data) that is needed to evaluate the status of, and changes affecting, hydrologic systems/units (e.g., watersheds, aquifers) of interest precipitation data. Fortunately, satellite-based precipitation data is now providing viable alternatives. The students will be trained on extracting temporal precipitation data (1998-present) over Libya from TRMM data, and temporal (2002-present) mass variations over the Nubian aquifer from GRACE data. They will then use the extracted data to generate trend images to identify areas that are getting wetter (more precipitation and increasing mass with time) or drier (less precipitation and less mass with time).

(6) Assessment of groundwater potential in varying geologic and hydrogeologic settings

Students will be introduced to case studies conducted in various geologic settings for the purpose of identifying typical reservoir types to be found in such settings and the criteria that one could use to locate such reservoirs using remotely acquired data together with traditional data sources (geochemistry, geophysics, GIS). Three types of settings will be investigated: (1) transcurrent fault systems using the Najd Fault System of the Arabian-

Nubian Shield and the Halendale fault system in the Mojave Desert as our study areas, (2) rifting systems using the Red Sea rift as our case study, and (3) fold and thrust belts using the Quetta region, in the Pakistani Himalayas as the study area.

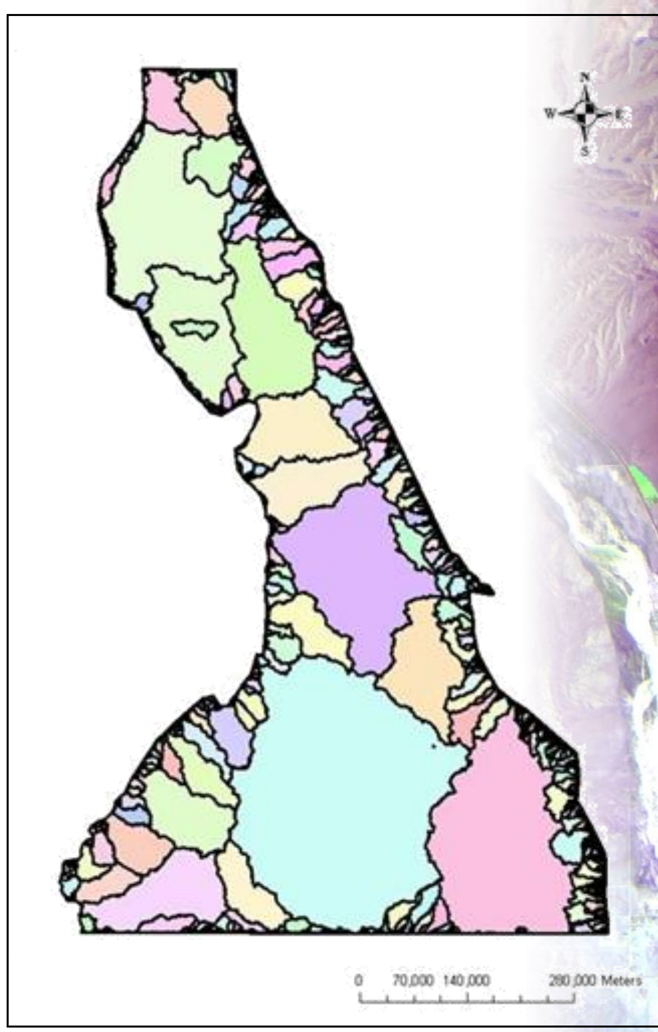
Hydrogeology Field Course

Corse Description

This is an applied hydrogeology field course designed to educate and train students in OSHA 40 hour hazwoper training, environmental surface geophysics, well drilling and installation, aquifer testing, groundwater sampling and testing, and remediation.

- OSHA 40-hour training
- Emergency spill response
- Personal protection equipment
- Bioremediation
- Pump & Treat systems
- Soil vapor extraction
- Air sparging
- Remedial investigation & feasibility study
- Magnetic methods
- Electromagnetic methods
- Surface resistivity methods
- Shallow seismic methods
- Very low frequency (VLF)
- Ground penetrating radar (GPR)
- Step draw-down pumping test
- Forty-hour pumping test followed by recovery test
- Slug and bail tests
- Data Processing using computer software
- Water level recorders, measuring equipment and data loggers
- Hollow-stem auger drilling and well installation
- Rotary drilling with mud and air
- Cable tool drilling
- Direct Push Technology
- Sample collection and description; cuttings, split spoon and Shelby tool
- Borehole geophysics
- Monitoring well design; Installation and development of wells
- Quality control and quality assurance procedures
- Ground-water sampling equipment and procedures
- Field hydrochemical equipment and procedures
- Vadose zone sampling (water, gas)
- Free product (NAPL) monitoring

Rainfall-Runoff Modeling using SWAT



Course Description

This section of the course focuses on the theory and application of hydrologic modeling. The principal of every scientific discipline is to construct and test theoretical models using testable assumptions. Building computer models takes this practice to a new level. This course will teach the student to build and understand cutting edge digital models so that they may then go and apply these useful skills to a broad range or real life applications. The course focuses on understanding the theoretical basis on which these models are constructed, as well as practical and useful applications. It is expected that the theoretical understanding of how real world hydrology is represented in sophisticated modeling software that the student can then take their model significantly closer to reality.

Areas of Focus:

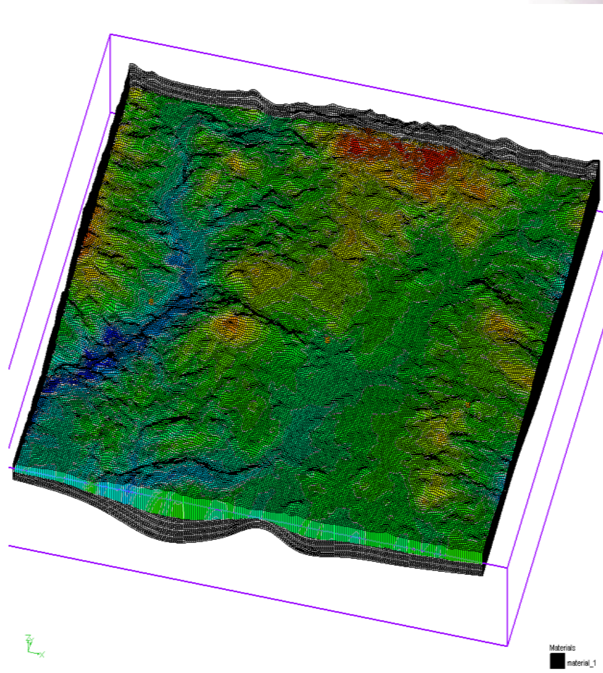
- Principles of Hydrologic Models
  - *Theory*
  - *Application*

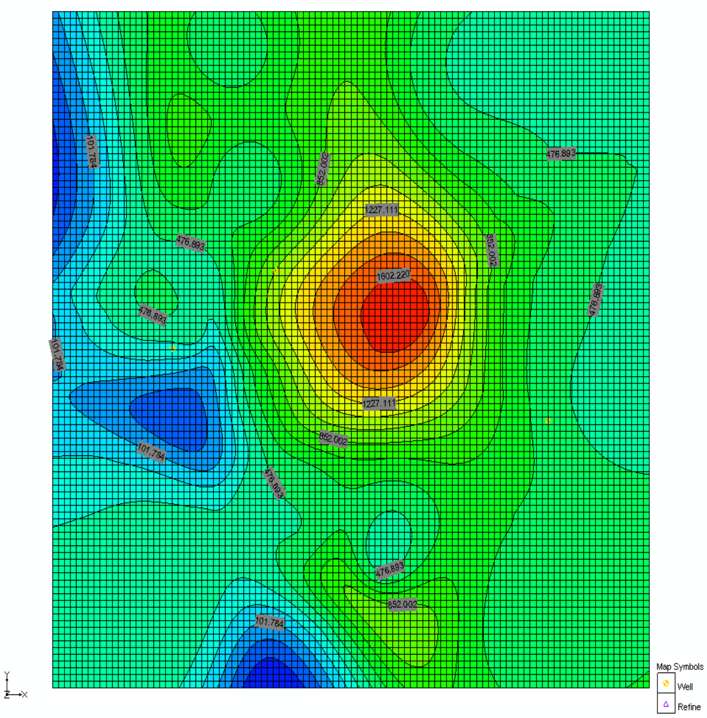
- Introduction to Rainfall-Runoff Models
  - *Data Sources*
  - *Processing*
- Introduction to Modeling Inputs and Databases
  - *Processing*
  - *Parameter Configuration*
  - *Conceptual Tests*
- Soil Water and Assessment Tool (SWAT)
  - *Setup*
  - *Simulation*
  - Sensitivity Analysis & Calibration of Models

Groundwater Modeling MODFLOW

Course Description

This section of the course focuses on the theory and application of groundwater modeling. In particular will be the fundamental principles as well as hands on training with sophisticated groundwater models such as GMS and Visual MODFLOW. The USGS's Modular 3-D Finite Difference Groundwater Flow Model (MODFLOW) code will be used during this training section (McDonald and Harbaugh, 1988; Harbaugh et al., 2000). This code was chosen due to its wide acceptance, use, ability to model in three dimensions, verification of model for a wide range of field problems, and given the fact that conceptual models could be accurately represented within MODFLOW's framework. Visual MODFLOW will be the pre- and post-processor to facilitate the model setup and input/output processes.





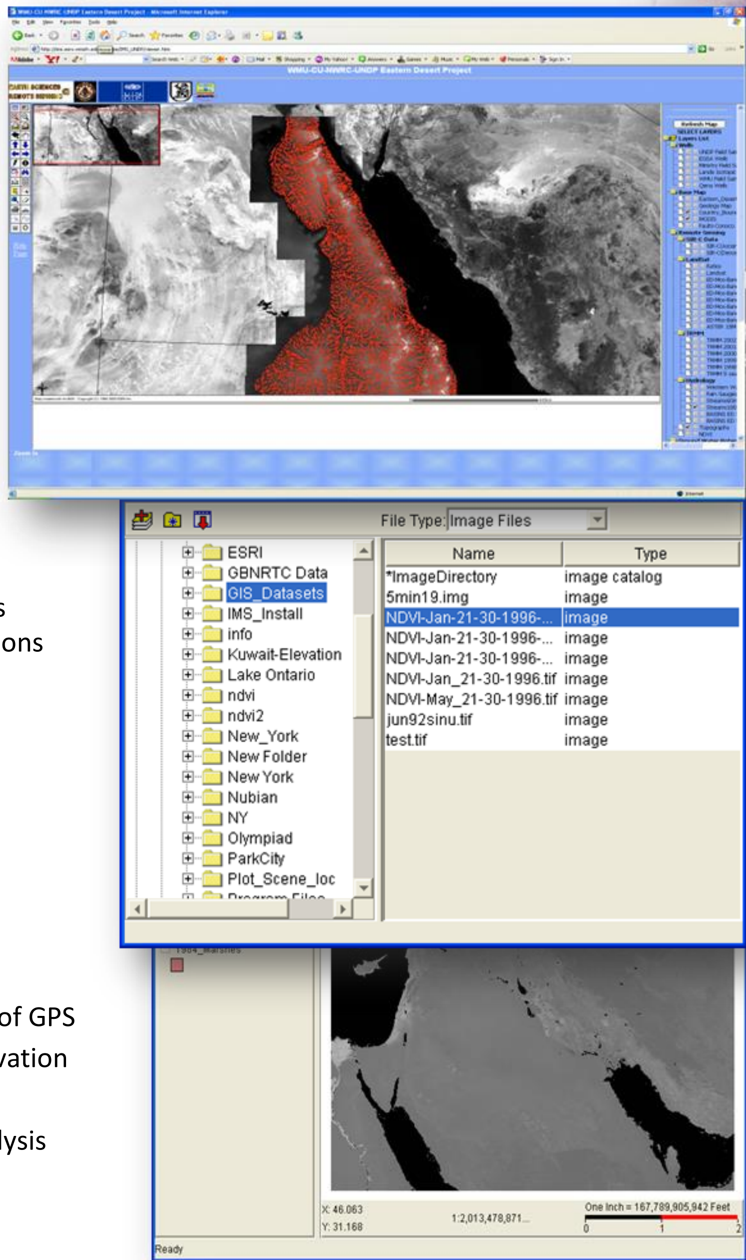
Areas of Focus:

- Model Inputs
  - Base maps
  - Boundary Conditions (General Head, Constant)
  - Well/Lithologic Data
  - *Theory*
  - *Application*
- Introduction to Groundwater Models
  - *Data Sources*
  - *Processing*
- Introduction to Modeling Inputs
  - *Processing*
  - *Parameter Configuration*
- Construction of Visual MODFLOW Model
  - *Setup*
  - *Simulations*

Applications of Geographic Information Systems (GIS) in Hydrogeology

Course Description

The course will cover the fundamentals of spatial data analysis and GIS technologies since the students cannot start dealing with applications unless they understand the fundamentals. **Thus the main goal for this course is to u**nderstand the fundamentals of GIS technologies and related fields and numerical and spatial analysis techniques commonly used in the analysis of geological and environmental data sets and applications. The participants will be introduced and become familiar with GIS components and concepts including:



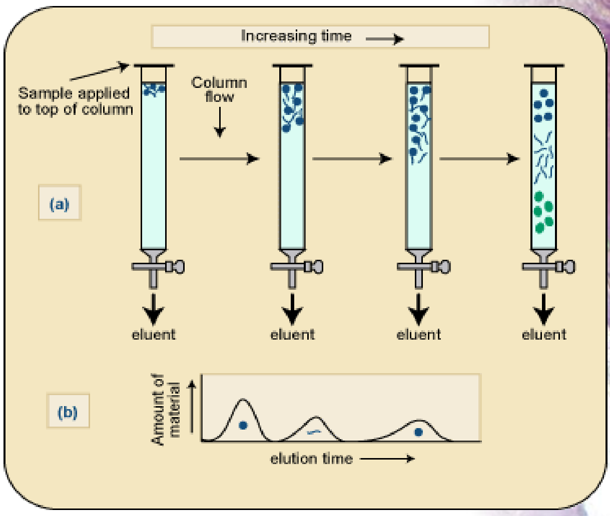
- ○ Geographic Information Systems
- ○ Coordinate systems and projections
- ○ Representation of Spatial Data
- ○ Data Types
  - Raster Data
  - Vector Data
- ○ Map Projections
- ○ Spatial Data Input
- ○ Data conversion
- ○ Editing Spatial Data
- ○ Data Attributes
- ○ Fundamentals and Applications of GPS
- ○ Generating and Interpreting Elevation Data
- ○ Watershed Delineation and Analysis

- Spatial Data Models
- Spatial Interpolation
  - ○ Triangulation
  - ○ Theissen Polygons
  - ○ Inverse Distance Weighted
  - ○ Radial Basis Function
  - ○ Global Polynomial
  - ○ Kriging
- Future trends in GIS
  - ○ Web-based GIS
  - ○ 3-D visualization (Geowall applications)

Application of Geochemistry in Hydrogeology

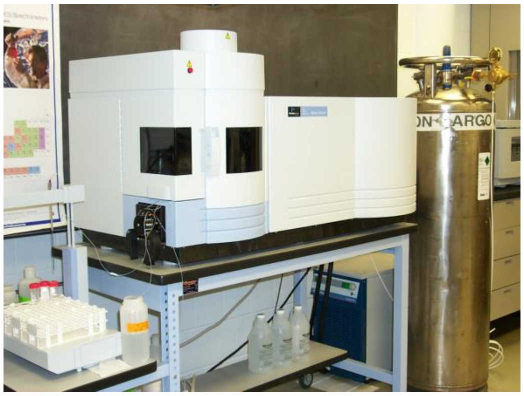
Course Description

This course is designed as an overview of the basic principles and applications of hydrology, geochemistry, and isotopic methods for the evaluation of groundwater resources. The course will consist of lectures and practical problems for the participants to solve. Lecture notes will be provided to all participants. A general outline of the course is given below.



Hydrology:

- Precipitation Patterns
- Watersheds
- Recharge and Runoff
- Vadose Zone
- Confined and Unconfined Aquifers
- Groundwater Flow Models



Geochemistry:

- Solutes in rain and snow
- Marine aerosols and dry fallout
- Soil porewaters and salts
- Groundwater chemistry
- Effects of microorganisms on groundwater chemistry
- Dissolution and precipitation reactions in aquifers
- Trace gases and excess air in groundwater
- Use of trace gases for groundwater dating (CFCs, SF_6)

Isotopic methods:

- Stable isotopes of hydrogen, carbon, oxygen, sulfur, and strontium
- Stable isotopes in precipitation
- Isotopic effects of evaporation
- Tracing origins of solutes using stable isotopes
- Radioactive isotopes (tritium, ^{14}C, ^{36}Cl, ^{39}Ar, ^{81}Kr, ^{85}Kr, U-series)
- Radioactivity in precipitation and groundwater
- Groundwater dating using radioactive isotopes

Computer Science Applications in Hydrogeology

Corse Description

This course will focus on various ways in which computers can be used to assist the hydrogeologists and geoscientists. The student will learn various applications of data management and visualization, as well as an introduction to the concepts of computer programming and computer science applications. The student will also learn how to access, download, and process various global data sets that could be used in hydrologic, environmental, and geologic investigations.


```
<?xml version="1.0" encoding="UTF-8"?>
<ARCXML version="1.1">
	<CONFIG>
		<ENVIRONMENT>
			<LOCALE country="GB" language="en"/>
			<UIFONT color="0,0,0" name="Arial" size="12" style="regular"/>
			<SCREEN dpi="96"/>
		</ENVIRONMENT>
		<MAP dynamic="true">
			<PROPERTIES>
				<ENVELOPE name="Initial_Extent" minx="000000" miny="2200000" maxx="500000" maxy="3465100"/>
				<ENVELOPE name="Extent_Limit" minx="000000" miny="2000000" maxx="500000" maxy="3500000"/>
				<FEATURECOORDSYS id="32636"/>
				<FILTERCOORDSYS id="32636"/>
				<MAPUNITS units="meters"/>
				<BACKGROUND color="255,255,255" transcolor="255,255,255"/>
			</PROPERTIES>
			<WORKSPACES>
				<SHAPEWORKSPACE name="ws-1" directory="E:\ED_2004-Fall"/>
				<SDEWORKSPACE name="sde_ws-0" server="GIS4" instance="sde:oracle" database="GIS" user="xxxx" encrypted="false"
				password="xxxx" />
			</WORKSPACES>
			<LAYER name="UNDP Field Samples" type="featureclass" id="10" visible="false">
				<DATASET name="undp_wells" type="point" workspace="ws-1"/>
				<COORDSYS id="4326"/>
				<SIMPLERENDERER>
					<TRUETYPEMARKERSYMBOL character="33" angle="0" antialiasing="false" font="ESRI Default Marker"
					fontcolor="175,0,225" fontsize="14" fontstyle="regular" overlap="true" rotatemethod="mod_arithmetic"
			transparency="1" usecentroid="true"/>
				</SIMPLERENDERER>
			</LAYER>
			<LAYER name="Shallow Nubian" type="featureclass" id="71" visible="false">
				<DATASET name="SDE.Shallow_Nubian" type="line" workspace="sde_ws-0"/>
				<COORDSYS id="4326"/>
				<SIMPLERENDERER>
					<SIMPLELINESYMBOL antialiasing="false" captype="butt" color="200,200,20" jointype="round" transparency="1"
				overlap="true" type="solid" width="3"/>
				</SIMPLERENDERER>
			</LAYER>
		</MAP>
	</CONFIG>
</ARCXML>
```

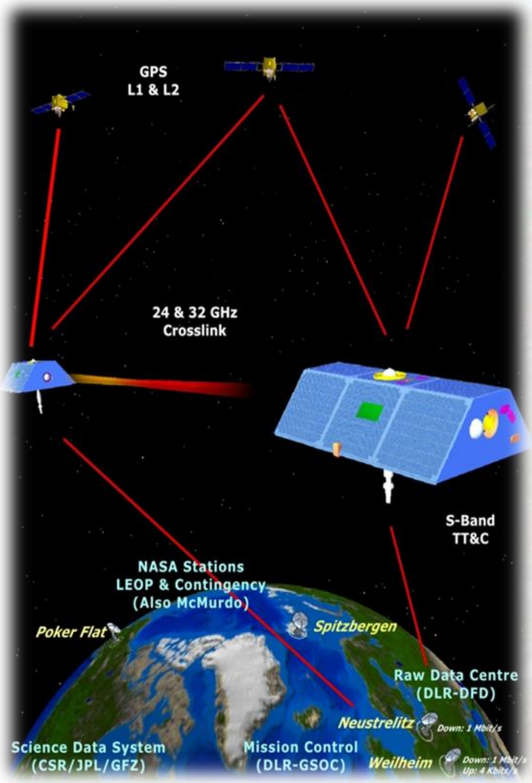

- Introduction and Construction of a Web Based GIS
    - Construction and Hosting of an web-based GIS (ArcGIS)
    - Maintenance of ArcGIS
    - Development and Expansion
    - Tools
- Introduction to Computer Sciences Concepts
    - Digital Logic
    - Computer Programming Concepts

    - Introduction to Images and Shape Files
- Digital Extraction and processing of Hydrologic Global Data Sets
    - TRMM (Tropical Rainfall Measuring Mission)
    - CMAP (CPC Merged Analysis of Precipitation)
    - GRACE (Gravity Recovery and Climate Experiment)
    - HWSD (Harmonized World Soil Database)
    - GLCC (Global Land Cover Characterization)
    - NOAA climatic database

GRACE: A Tool for Monitoring Hydrogeology

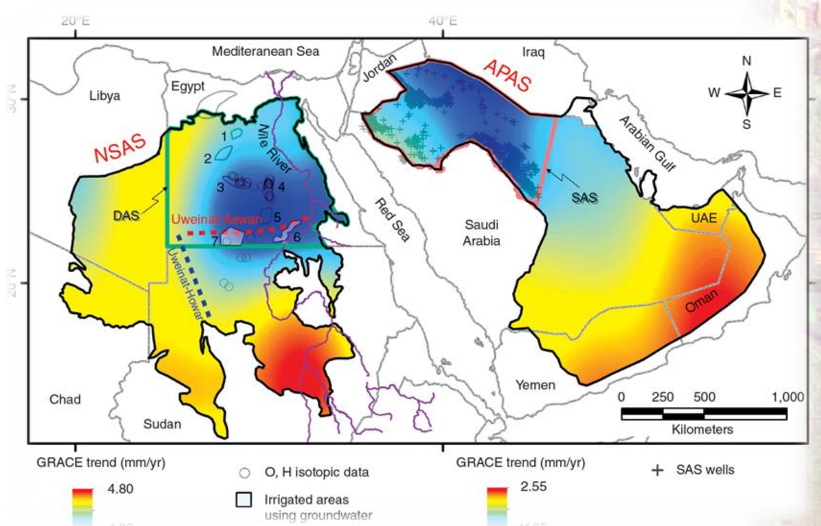
Course Description

The Gravity Recovery and Climate Experiment (GRACE) satellite mission is a joint project between the National Aeronautics and Space Admiration (NASA) in the United States and the Deutschen Zentrum für Luft und Raumfahrt (DLR) in Germany. GRACE was launched in March 2002 to map the temporal variations in the Earth's global gravity field on a monthly basis as well as the Earth's static gravity field with unprecedented accuracy. This course will focus on the use of GRACE in hydrological applications. The applicant will learn the basics of GRACE data, how to process the GRACE solutions and how to apply GRACE data for hydrological and environmental problems.



A general outline of the course is given below.

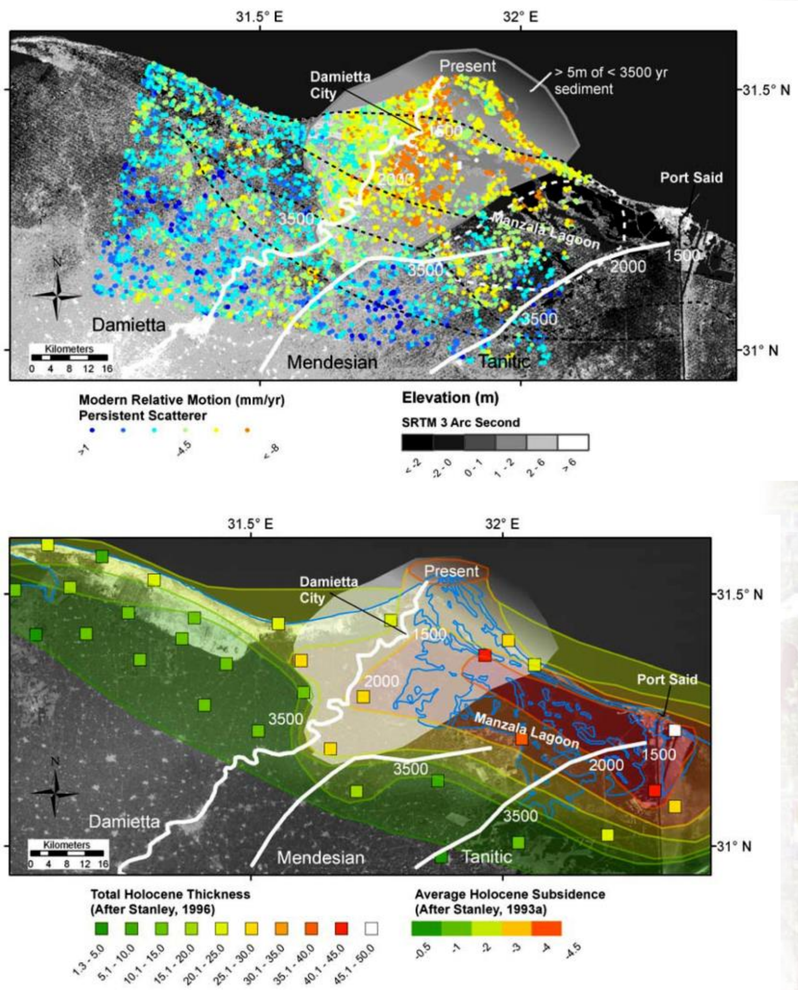
- GRACE basics
  - What is GRACE mission?
  - GRACE partners
  - GRACE data centers
  - GRACE data products
- GRACE data processing
  - Destripping GRACE solutions
  - Smoothing GRACE solutions
  - Rescaling GRACE data
  - Leakage eerrors
- GRACE bi-products
  - Standard deviation images
  - Amplitude of Annual Cycle
  - Phase of Annual Cycle
  - Trend images



Radar Interferometry: A Tool for Environmental & Hydrogeologic Applications:

Course Description

Imaging radar is an active illumination system. An antenna, mounted on a platform, transmits a radar signal in a side-looking direction towards the Earth's surface. The reflected pulse is backscattered from the surface and received at the same antenna. In the case of the Synthetic Aperture Radar (SAR), the amplitude and the phase of the received echo (which are used during the focusing process to construct the image) are recorded in contrast to the Real Aperture Radar (RAR) where only the amplitude is recorded.



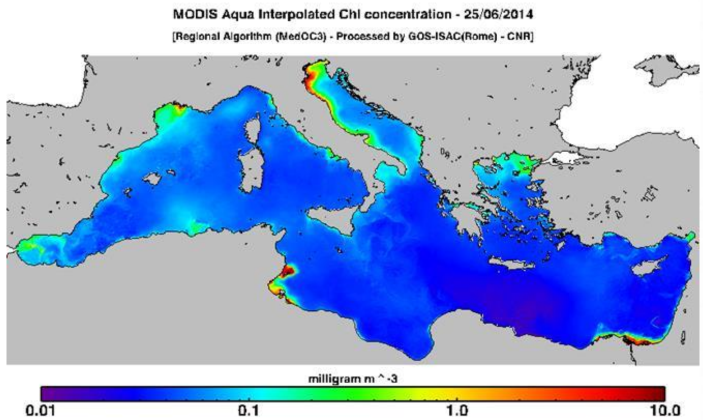
Interferometry is a new geodetic technique calculates the interference pattern caused by the difference in phase between two images acquired by a spaceborne SAR system at two distinct times. The resulting interferogram is a contour map of the change in distance between the ground and the radar instrument. Interferometric synthetic aperture radar (InSAR) processing makes use of the difference in phase between two radar scenes to determine precise differences in range to a target and to subsequently determine the exact surface location, and subtle changes in topography.

In this course the applicant will learn about the following:

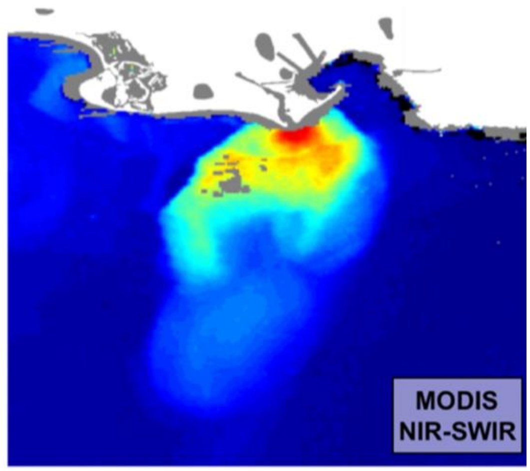
(1) Radar images, Principles of radar phase and interferometry, and limits of interferometric measurements;
(2) Constructing and improving interferograms using different radar images (i.e., ENVISAT, ERS) applying two pass, three pass, SBAS, permanent scaterer techniques;
(3) Work on real data pertaining to subsidence in the Nile Delta and landslides in Saudi Arabia

Applications of Remote Sensing in Aquatic Environmental Sciences:
Course Description

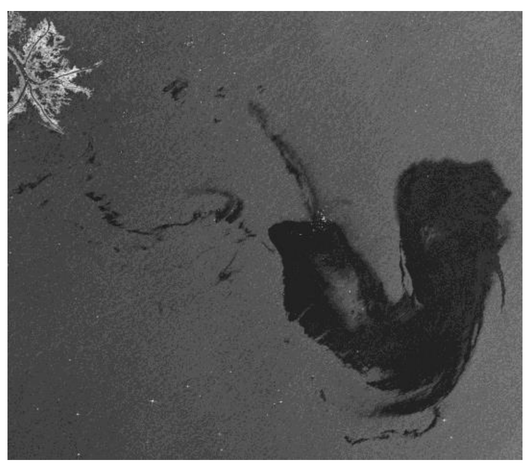
There are growing applications of remote sensing in the general area of aquatic remote sensing using VNIR, thermal infrared and radar. Examples of such applications include the use of VNIR radiation to map the distribution of algal blooms. The blooms are found in both fresh and salt water primarily due to the introduction of excessive nutrients into the water bodies. Many of the satellite-based detection algorithms for algal blooms take advantage of the chlorophyll-a spectral signature.



There are growing needs and usage for desalination plants and nuclear hydropower stations especially in arid and hyper-arid areas. The effluents from these stations are released in nearby water bodies and could have adverse effects on the ecosystems in these areas. Hence there is a need to map the spatial and temporal distribution of these releases. Because the effluents usually have a higher temperature than the media in which they are being released, thermal infrared could be readily used to map such discharges.



The capability of SAR to detect oil slicks over the sea surface is well known and proven by several studies, most of which is based on the detection of dark spotted areas. This is because surfaces covered by oil spills act as mirrors reflecting radar energy away from the sensor.



In this course the applicant will learn about the following:

Mapping algal blooms using VNIR data, effluent releases using thermal infrared, and oil spills using radar images.

Participation in Ongoing Projects

The students receiving training at the ESRS will have an opportunity to apply the gained expertise to ongoing research projects. Their participation in these projects will be considered as added training and will largely depend on the time span they will be spending at WMU.

Evaluating subsidence in the Delta using radar (NSF-funded project)

We are using temporal satellite radar data to measure the spatial and temporal variations in subsidence rates across the entire Delta, identify the nature of the factors controlling modern subsidence, and predict the Delta response to these forcing factors over the next century. The interplay between natural and anthropogenic parameters controls subsidence rates and determines whether a delta progrades or erodes. Natural parameters include tectonic movements and millennial-to-decadal climate changes accompanied by wide swings in aridity and moisture and sea level fluctuations, whereas parameters based on human activity are probably largely related to extraction of groundwater and natural gas and impoundment of theNileRiverby the Aswan High Dam. Our preliminary radar interferometric (ERS-1 and ERS-2) studies over the northeastern section of the Nile Delta indicate that modern subsidence rates are high (up to 8 mm/yr) compared to average Holocene subsidence rates and that their spatial distribution is inconsistent with the distribution reported for the Holocene. We are now expanding the ERS-based study area to include the entire Nile Delta. A geodetic component will be included to provide ground based measurements and calibrate the motions inferred from the interferometric analyses. The study will result in the assessment of subsidence rates throughout the entire Nile Delta and the identification of the factors controlling the subsidence. Because we will be developing predictive tools that can potentially identify areas of high subsidence rates that are prone to sea water encroachment, our findings could be used to develop sound strategic plans for combating and/or modulating these adverse effects. In this respect our findings could be vital to the livelihood of at least half ofEgypt's 80 million citizens that inhabit the Delta and depend on it for their sustenance. All proposed tasks will be accomplished jointly by US scientists (fromWesternMichiganUniversityand theUniversityofToledo) and their Egyptian colleagues (from the National Authority for Remote Sensing and Space Sciences) who will be receiving training inEgyptandUSAon radar interferometric and geodetic applications.

Use of GRACE, remote sensing, and traditional datasets for modeling time-dependent water portioning on continental scale: Case study from African Continent (NASA funded project)

We are developing and applying an interdisciplinary system approach involving analysis of GRACE, remote sensing, and relevant data sets (e.g., stream flow) along with hydrologic modeling to accomplish the following: (1) develop quantitative macro-scale hydrologic distributed grid models (grid size: 0.5° x 0.5°) for the African continent that can account for vertical and lateral mass movement, (2) calibrate the model against temporal measurements from GRACE over selected suite of grid cells that have high signal/noise ratio, and (3) conduct simulations using the calibrated hydrologic model with forcing datasets from global climate models to predict the response of land and/or hydrologic units (e.g., regional vegetation [forest, crops], soil water storage, wetlands, lakes, streams, shallow groundwater, etc) to projected climatic changes in Africa. These activities build on, and take advantage of, our recent findings that indicate that the temporal mass variations from the GRACE solutions, acquired over northern and central Africa and as far as 10° south of the Equator, smoothed using a 250 km radius Gaussian, are largely controlled by elements of the hydrologic cycle (e.g., runoff, infiltration, ET, and recharge), and have not been obscured by noise as previously thought. The work will provide a replicable model that can be used on regional and continental scales world-wide.

Integration of GRACE Data for a better understanding of the hydrologic setting of the Nubian Aquifer (NASA-funded project)

We are developing and applying an interdisciplinary system approach (involving analyses of GRACE gravity, remote sensing, and geochemical data, along with hydrologic modeling) to assess and calibrate GRACE data for monitoring groundwater recharge, discharge, and flow in large-scale aquifers. The Nubian Aquifer of North Africa was chosen as a test site, because its extensive areal distribution allows temporal gravity variations to be detected with accuracy; its hyperarid conditions facilitate calibration of GRACE gravity data; and its potential for demonstrating the utility of GRACE data to resolve issues pertaining to recharge and discharge rates, the magnitude and direction of groundwater flow, and the connectivity of subbasins. Results obtained from this research could provide straightforward techniques for monitoring storage variability in groundwater resources in arid and semi-arid countries worldwide. This work is being conducted jointly by scientists from Western Michigan University, Argonne National Laboratory, the University of Illinois at Chicago, the Macquarie University (Sydney, Australia), and Cairo University (Cairo, Egypt).

Transcurrent Fault Evaluation for Water Resource Investigation of Este Groundwater Basin (Mojave Water Agency-funded project)

New research on fault-groundwater interaction in arid regions of the Middle-East has revealed the potential that fault structures can be potential groundwater conduits. Faults are normally viewed as groundwater barriers especially in alluvial systems. The Helendale fault which crosses through the Este Groundwater Basin has always been seen as a barrier to groundwater movement (USGS, 2004). Due to this thought process much of the potential aerial recharge to the basin has been interpreted as being limited. This research will evaluate through both field and laboratory work the processes that govern groundwater movement in and around the Helendale fault within the bedrock.

Developing Cost-effective Methodologies for Groundwater Assessment and Exploration in Sinai (NATO-funded project)

An integrated approach utilizing field, geochemical, isotopic, geophysical, modeling, remote sensing, and GIS technologies is being used to assess the groundwater potential in the Sinai Peninsula. Due to the inadequate number of hydrologic monitoring stations in Egypt, we are installing a telemetric rain gauge and steam flow monitoring stations in Sinai to aid in calibrating continuous rainfall-runoff models. In addition, recharge rates are being estimated using field-based techniques (Chloride mass balance and soil temperature probes). This integrated approach will enable better characterization and monitoring of key reservoirs of, and fluxes to, the water cycles in these areas.

Detailed Studies on landslides in Jazan area in Saudi Arabia (funded by: Saudi Geological Survey)

This is a collaborative project to develop a web-based GIS relational database for geological data sets for Saudi Arabia. It will comprise digital topographic, geologic maps, and remote sensing, seismic, geochronologic, geochemical, and isotopic data. We will compile and organize datasets, develop metadata files, and assemble online tools for visualization. The tasks will be conducted jointly by scientists from the Department of Geosciences, Western Michigan University, and King Saud University. The data generated using funding from this project were integrated with other available data sets for Saudi Arabia and hosted on a web-based GIS. The web-based GIS is intended to facilitate the research activities conducted in Saudi Arabia by national and international scientists by bringing together the most comprehensive digital database for Saudi Arabia and by introducing customized online tools for the visualization and analysis of these data sets. Scientists from the Earth Sciences Remote Sensing (ESRS) facility at Western Michigan University (WMU) propose to conduct the remote sensing and GIS research activities/components for the Jazan Landslide project. This project will be implemented jointly by the Saudi Geological Survey (SGS) together with the University of King Abdul Aziz. The ESRS will be undertaking two main tasks. The first task involves compilation and analysis of remote sensing data in conjunction with other data sets to accomplish the following: (1) detecting changes in topography using temporal radar interferometry, (2) detecting changes in morphology using temporal ASTER imagery (VNIR bands), and (3) analysis of spatial relationships of various data sets in a GIS for a better understanding of the distribution, nature, and controlling factors for landslides. In addition to the two major tasks outlined above, the ESRS will be providing additional consulting services and additional products that will assist the SGS in implementing a number of project-related tasks that they will be undertaking. Examples include: (1) construction of detailed topographic maps, (2) investigating earthquakes and their impacts on the study area, (3) investigating the environmental and climatic impacts on the study area using 3-hourly satellite precipitation data (TRMM data), (4) documenting the project results, and writing reports, (4) participating in one or more field trips to the study area, and (5) acting in an advisory capacity to the SGS as needed for relevant tasks (e.g., deployment and analysis of Lidar technologies; methodologies for protection and reduction of landslide hazards; construction of an Early Warning System).

Use of GRACE Data to Estimate Temporal Changes in Terrestrial Water Storage (TWS) Across the Empty Quarter & Surroundings

This a collaborative project with the Saudi Geological Survey aimed at utilization of the Gravity Recovery and Climate Experiment (GRACE) satellite mission (launched in March 2002) to map the temporal variations in the Earth’s global gravity field on a monthly basis (Tapley et al., 2004) over the Kingdom of Saudi Arabia. The variability in these gravity field solutions represents geophysical responses associated with redistribution of mass at or near the Earth’s surface, where mass variations are likely to occur on the time scales examined by GRACE measurements. Generally, the largest time-variable gravity signals observable in GRACE data are expected to come from changes in the distribution of water and snow stored on land (Wahr et al., 1998).

We will be analyzing all available monthly gravity field solutions (RL04 unconstrained solutions) that span the period August 2002 through present from the GRACE database provided by the University of Texas Center of Space Research (CSR). The CSR RL04 gravity field solutions will be processed as follows: (1) The temporal mean will be removed from each of the spherical harmonic coefficients; (2) correlated errors will be reduced by applying destriping methods developed by Swenson and Wahr (2006); (3) spherical harmonic coefficients will be converted to grids (0.5° × 0.5°) of equivalent water thickness using a Gaussian smoothing function with a radius of 250 km; and (4) standard deviation (SD) images and trend images will be generated from the equivalent water thickness grids.

The spatial distribution of GRACE SD and Trend data will be compared to other relevant geologic, topographic, and hydrologic data in a Web-based GIS environment (available at www.esrs.wmich.edu/webmap) in order to identify areas exhibiting: (1) large temporal mass variations, (2) trends (+ve or –ve) in these mass variations and (3) investigate the forcing parameters giving rise to these variations. The GIS will include all relevant data including: (1) GRACE monthly (equivalent water thickness) SD and trend images, and amplitude and phase of annual cycle images; (2) monthly, annual, and total (2002–present) precipitation images, SD images, and amplitude and phase cycle images, all extracted from Tropical Rainfall Measuring Mission (TRMM) data; (3) digital elevation data (DEM) extracted from Shuttle Radar Topography Mission (SRTM) data products (pixel size: 1 km); (4) slope data extracted from DEM; (5) geologic maps; (6) false-color Landsat Thematic Mapper (TM) data (pixel size: 90 m) and ASTER images (pixel size: 30 m); (7) stream networks and watershed boundaries extracted (TOPAZ; Garbrecht and Martz, 1995) from the SRTM dataset; (8) lithologic maps derived from TM and ASTER images; (9) temporal variations in extraction rates, and (10) temporal variations in distribution of irrigated lands.

The tasks to be accomplished include:

- Acquisition and digitization of all relevant data sets
- Download and co-registration of remote sensing data (e.g., GRACE, ASTER, TRMM, Landsat)
- Processing of GRACE and TRMM data and generation of derived products (e.g., SD, trend images)
- Generation of a web-based GIS to host the generated data
- Spatial analysis of the derived products in a GIS environment to identify the spatial and temporal mass variations and their nature (+ve or –ve trends)
- Identify the factors controlling the mass variations including natural (e.g., climate change) and man-made factors (e.g., water extraction)

Remote Sensing Applications in Monitoring the Spatial and Temporal distribution of Algal Blooms in Southwest Florida

The students will develop methods to respond to major coastal resource or public health impacts associated with harmful algae blooms (HABs) and will investigate the driving forces for the propagation of these blooms. The students will be analyzing space-borne remote sensing data to study algal blooms; specifically the visible and near-infrared spectral bands. The identification of algal blooms from space-borne observations by the students will be enabled because of the: (1) distinct spectral signature of the algal bloom compared to that of the surrounding water; and (2) large spectral variations over an area within a short interval arising from the explosion in algal population. The students will be using MODIS data and the NASA SeaDAS images to extract products indicative of bloom occurrences such as Chlorophyll-a images, sea surface temperature, turbidity, etc. The students will then use archival data pertaining to algal bloom occurrences to derive statistical relationships describing the factors indicative of bloom occurrences and use these relationships as predictive tools.

IV. Facilities

Computing Facility

In August 2004, Dr. Sultan joined the faculty of Western Michigan's Department of Geosciences as chairman. Using startup funds from WMU, Sultan and his research team developed a state of the art computation and remote sensing facility. The Earth Sciences Remote Sensing (ESRS) facility is being used for conducting RS analysis and GIS applications, as well as development and distribution of geologic databases.
The facility is a distributed system consisting of a network of four servers (Windows), and twelve workstations. The four servers provide support for web access, file service, database and ARCGIS services, as well as spinning data backup. Individuals operate from nine powerful workstations which include Intel I7 Core2 Quad processors, and two laptop computers, running a combination of Windows and Ubuntu Linux. These machines and the printers are networked together on a massive 1GB network to allow sharing of all of their resources. This network is linked into the Internet through WMU's backbone. The network servers have over 50 TB of disk space between them. Each of the PCs has a 2 19-in. monitors, memory ranging from 2 GB to 12 GB, and local storage ranging from 500 GB to 5 TB of local storage. One laptop is a Pentium 4 machine with 512MB of memory and 40 GB hard drives; the other laptop is a Pentium system with a 4GB hard drive. Two 14GB Exabyte 8-mm tape drives are available for importing and archiving data. For importing hard copy data, the facility has a digitizing tablet (Calcomp Drawing Board III) with a 3-ft x 4-ft active area, a 2400 dpi large format (40 in. wide) IDEAL color scanner, a 500-dpi large-format (38 in. wide) black-and-white scanner, a 3200 dpi 11x17" flatbed scanner for transparency and opaque originals, a slide scanner, and a smaller (8 in. wide) color scanner. Digital Data can be read from CD, DVD, and 8mm tapes. Multiple CD-RW and DVD+R drives are used for data archiving on CD-ROM and DVD. Output is handled by a networked Xerox Phaser color laser printer, a networked Lexmark BW laser printer, a large format (42" wide) HP designjet 500PS color printer, a SPARC E laser printer, a Polaroid HR-6000 film recorder, an inkjet color printer, and a Kodak dye-sublimation printer. The major computational software packages used are ENVI, PCI Geomatica, DORIS, ROI_PAC ARC/INFO, WMS, GMS and SWAT. ENVI is a flexible image-processing package on which all of the image manipulation is done. PCI is being used for extraction of elevation data from satellite and aerial photography. DORIS and ROI_PAC are radar interferometry packages which will be used extensively in this project. ARC/INFO is a GIS package used to store and help interpret non-image data. The use of ARCSDE enables querying of our Oracle databases directly from ARCGIS. GMS and WMS and SWAT packages are used for ground water flow and surface runoff modeling.

Receiving Station

In 2004, the Department of Geosciences acquired a real-time receiving station which downloads data from several satellites.

ASD Fieldspec Spectroradiometer

Also using startup funds from WMU, the ESRS facility is acquiring a hand-held VNIR spectroradiometer to further develop their research interests and applications in the general area of remote sensing. The spectroradiometer is hosted in the Earth Sciences Remote Sensing Facility and is used by the participant investigators in their respective disciplines. It is used for training students across the campus.

The spectroradiometer is a portable instrument, designed to take spectral radiance, irradiance and reflectance measurements in the 350 - 2500 nm spectral range. We have acquired optics for use in both aquatic and terrestrial studies.

GEOWALL

The ESRS facility is also setting up a new **GeoWall** at their new home at WMU. A GeoWall is an eight foot by six foot rear projection passive stereo wall, which enables users to examine subsurface models in a 3-D environment. Polarized stereo images are projected onto the screen from separate projectors. The user sees the image in three dimensions while wearing appropriately polarized glasses.

VI. Price List

Course Title	Length***	Price/week ($US; Single Person	Price/week ($US; 2-5 Persons)
Geologic & Environmental Remote Sensing Course	2/4 Weeks	2000	5000
Hydrogeology Field Course*	6 Weeks	2000	5000
Remote Sensing Digital Image Processing & Applications	2/4 Weeks	2000	5000
Rainfall-Runoff Modeling using SWAT	2/4 Weeks	2000	5000
Introduction to Groundwater Modeling	2/4 Weeks	2000	5000
Applications of Geographic Information Systems in Hydrogeology	2/4 Weeks	2000	5000
Application of Geochemistry in Hydrogeology	2/3 Weeks	2000	5000
Computer Science Applications in Hydrogeology	1/2 Weeks	2000	5000
GRACE: A Tool for Monitoring Hydrogelogy	2/4 Weeks	2000	5000
Radar Interferometry for Environmental & Hydrogeologic Applications	2/4 Weeks	2000	5000
Applications of Remote Sensing in Aquatic Environmental Sciences	1/2 Weeks	2000	5000
Participation in ongoing projects**	1 Week	1000	2500

* Each unit is for 1 week. Students can take as many as they need; Also, please examine the information on our hydrofield camp on our departmental website: http://www.wmich.edu/geology/academics/hydrogeology.html

** As part of the training the students can participate in all ongoing projects of their selection and for the period of their choice

***Two versions are available for each of the courses: condensed form/full course

N.B.: An addition $500/student/week for accommodation expenses (if required by student) on or off campus