

# Measuring regional difference in urban growth of Taipei city (Taiwan, China) by means of ENVI GIS and remote sensing data

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## Outline

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## Techniques

### Data

Landsat TM Images

Preliminary Data Processing

### Methods

K-means Algorithm

K-Means Clustering

K-means Classification: ENVI GIS

Land Cover Types

ENVI GIS Classification by K-means Method

Combining Classes

Creating Region Of Interest (ROI)

Subset Data via ROI

Regional Division of Taipei

Statistics of Change Detection

Post-Classification Data Processing

Statistical Processing

Computed Areas of the Land Cover Types

### Results

### Conclusions

### Discussion

### Thanks

### Bibliography

## Techniques

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## ENVI GIS

The research was performed using ENVI GIS software using Landsat TM images for years 1990 and 2005.

## K-means Algorithm

The landscapes in the study area at two multi-temporal Landsat TM images were classified using "K-means" algorithm. Different land use types were identified and classified. The area covered by each land cover class is compared for years 1990 and 2005 and dynamics analyzed.

## Land Cover Types

Changes in the selected land cover types were analyzed and human impacts on the natural landscapes detected. Classified land cover types were compared at both maps of land cover types for the years 1990 and 2005.

**Data**

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The screenshot displays the Global Land Cover Facility Earth Science Data Interface. The main map shows a satellite image of Taipei, Taiwan, with a red rectangular selection box over a specific area. The interface includes navigation tools, search bars, and a table of available imagery data.

Path/Row Search	Workspaces	Home	Map Search	Product Search	Path/Row Search	Workspaces
<p>TM            WRS-2, Path 117, Row 043            2005-08-17            USGS            Ortho, GLS2005            Taiwan            Online: 233.128            Compressed Size: 165 MB; Actual Size: 462 MB</p> <p>Info Download</p>						
224-943	Offline	2: 118/043	2005-10-18	ETM+	USGS	Ortho, GLS2005
224-425	Offline	2: 118/043	2006-03-11	ETM+	USGS	Ortho, GLS2005
227-768	Offline	1: 126/042	1972-11-01	MSS	USGS	Ortho, GLS1971
227-299	Offline	1: 126/043	1972-11-01	MSS	USGS	Ortho, GLS1971
227-814	Offline	1: 127/042	1976-01-07	MSS	USGS	Ortho, GLS1971
227-812	Offline	1: 127/043	1976-02-13	MSS	USGS	Ortho, GLS1971
233-128	Offline	2: 117/043	2005-08-17	TM	USGS	Ortho, GLS2005
233-129	Offline	2: 117/044	2004-07-12	TM	USGS	Ortho, GLS2005
233-544	Offline	2: 118/042	2004-12-10	TM	USGS	Ortho, GLS2005
234-836	Offline	2: 117/043	1990-07-22	TM	USGS	L1T
234-844	Offline	2: 118/043	1990-07-21	TM	USGS	L1T

## Source

Data: two Landsat TM imagery taken from the USGS website.

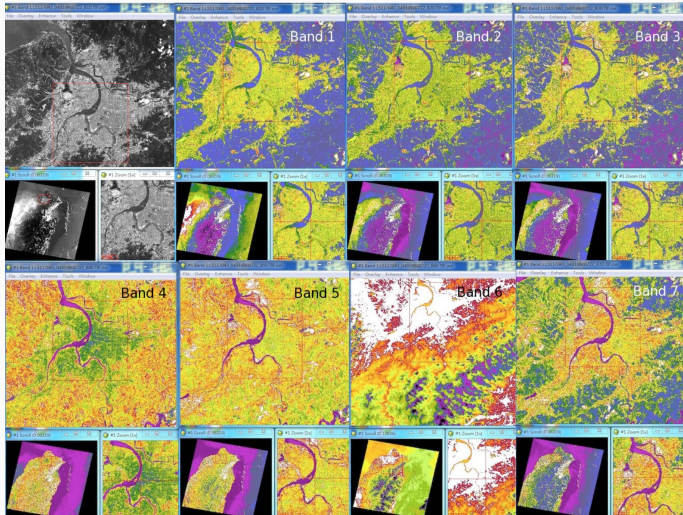
## Temporal comparison

Study period: imagery for summer periods of 1999-2005

## Examples

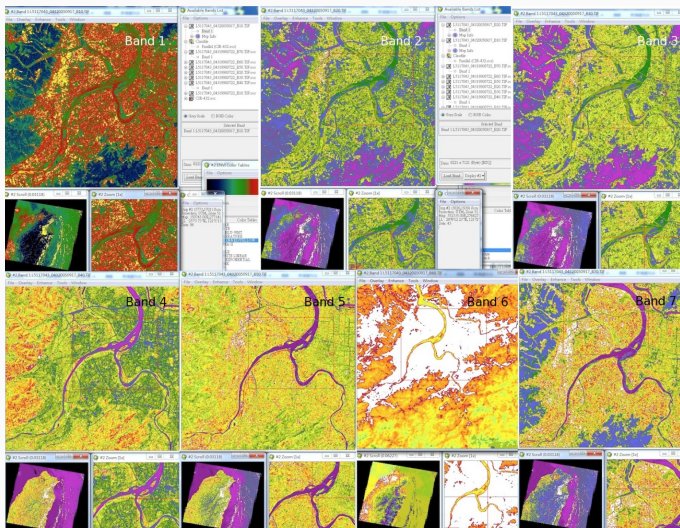
Spatial Comparison Selected territory focused on **3 different areas**: comparison of three districts of southern area of Taipei, Taiwan, along the Tamsui river

Landsat TM image (1990). Bands 1-7 (fragment). Color composites (ENVI)



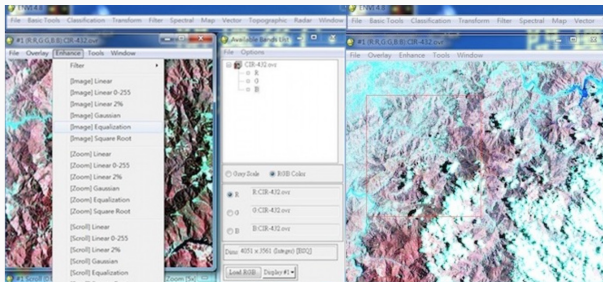


Landsat TM image (2005). Bands 1-7 (fragment). Color composites (ENVI)



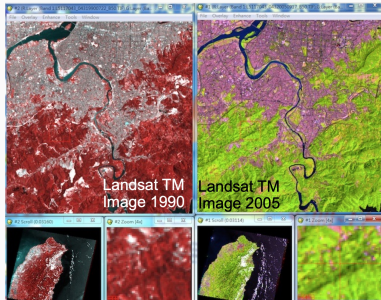
# Preliminary Data Processing

- Preliminary data processing: image contrast stretching.
- By default, ENVI displays images with a 2% linear contrast stretch.
- Histogram equalization contrast stretch was applied to the images in order to enhance the visual quality (better contrast)



## Methods

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Methods used in the current work include following steps:

- Data capture
- Color composition from 3 bands
- Defining Region of Interest (ROI)
- Selection of 3 different regions within the city area Image classification
- Combining classes and re-classification Post-processing
- Spatial analysis for 3 different areas of Taipei city

K-means algorithm procedure has 3 steps:

- Choosing the initial **centroids** for defined number of land classes
- **Assignment** of each pixel to the nearest centroid which represent certain land cover class
- Creating new centroids by taking the mean value of all pixels assigned to each previous land cover **class** (i.e. centroid).

**Looping** between the other steps 2 and 3:

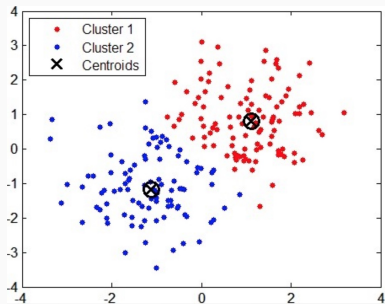
The difference between the old and the new centroids is '**inertia**'.

The algorithm repeats (loops) steps until the '**inertia**' is less than a **threshold**.

It **smoothes iteratively** the allocation of pixels until the centroids do not move significantly.

# K-Means Clustering

K-Means classification: general idea.

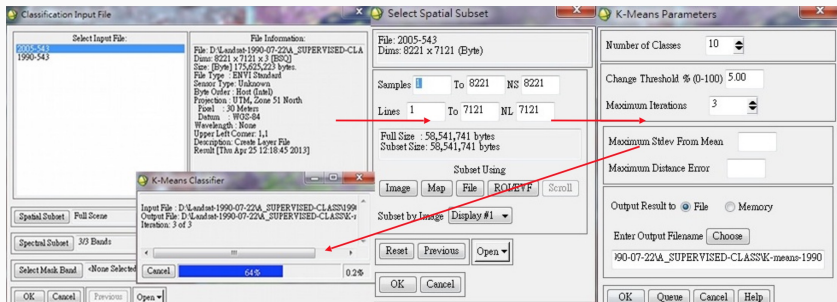


K-Means: a mathematical approach:

$$J(X, C) = \sum_{i=0}^n \min_{\mu_j \in C} (\|x_j - \mu_j\|^2)$$

- K-means is a flat clustering algorithm which is often used in classification techniques.
- The objective of K-means: to minimize the average squared Euclidean distance between the cluster centers (the means).
- K-means analysis allocates pixels into various clusters by defining the mathematical centroids of all clusters - groups of pixel with similar values of spectral reflectance, or digital number (DNs)
- K-means separates raster pixels in n clusters (groups of equal variance) by minimizing the 'inertia' criterion.

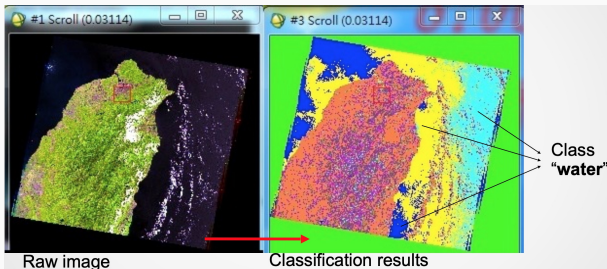
# K-means Classification by Means of ENVI GIS



# Land Cover Types

Classification of the land cover types in the city:

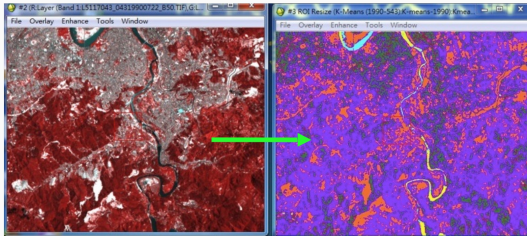
- Forests
- Urban areas – 2 (roads)
- Grasslands
- Open fields (little or no vegetation)
- Water areas
- Urban vegetation – 1 (bushes)
- Cultivated lands
- Agricultural facilities
- Urban vegetation –2 (parks and squares)
- Urban areas -2 (built-up surfaces)



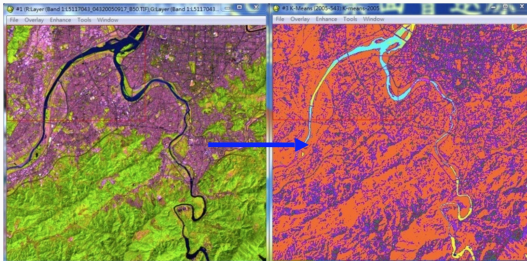


# ENVI GIS Classification by K-means Method

1990 Landsat TM scene classification (fragment). Random color visualization



2005 Landsat TM scene classification (fragment). Random color visualization



# Combining Classes

The screenshot displays the ENVI 4.8 interface with the 'Classification' menu open. The 'Combine Classes' option is highlighted. The 'Combine Classes Parameters' dialog is open, showing the following configuration:

- Select Input Class:** Water-river, Class 6, Class 7, Class 8, Class 9
- Select Output Class:** Class 1, Class 2, Water-deep, Water-shallow, Water-river
- Input Class:** (Empty)
- Output Class:** Water-river
- Combined Classes:** Water-deep -> Water-river, Water-shallow -> Water-river

The 'Combine Classes Output' dialog is also open, showing the following configuration:

- Remove Empty Classes ?** Yes
- Output Result to:** File
- Enter Output Filename:** Choose
- Filename:** 190-07-22\A\_SUPERVISED-CLASS\K-means-2005

# Creating Region Of Interest (ROI)

The screenshot illustrates the workflow for creating a Region of Interest (ROI) in ENVI GIS. The main window displays a satellite image of Taipei, Taiwan, with a red rectangular ROI overlaid. A blue arrow points from the ROI to the 'Available Bands List' window, which shows the ROI tool settings. Another blue arrow points from the ROI tool to the 'Enter ROI File Names' window, which shows a file explorer view of the 'ROI-Taipei.roi' file. A third blue arrow points from the 'Save ROIs to File' dialog box to the 'Select Input File to Subset via ROI' dialog box, which shows the 'ROI-Taipei.roi' file selected.

**Available Bands List**

ROI Name	Color	Points
ROI-Taipei	Red	101,582

**Enter ROI File Names**

名称	修改日期	類型
23April	2013/4/23 下午 0...	檔案資料夾
cir-432	2013/4/22 上午 1...	檔案資料夾
cir-432c1	2013/4/22 上午 1...	檔案資料夾
cir-432c2	2013/4/22 上午 1...	檔案資料夾
cir-432c3	2013/4/22 上午 1...	檔案資料夾
info	2013/4/22 上午 1...	檔案資料夾
ROI.roi	2013/4/23 上午 1...	ROI 檔案
ROI-Taipei.roi	2013/4/24 上午 0...	ROI 檔案

**Save ROIs to File**

Select Regions to Save:  
Region #1 (4051x3561) (Red) 101,582 points

Number of items selected: 1

Enter Output Filename [ .roi ] Choose  
D:\Landsat-1990-07-22\ROI-Taipei.roi

**Select Input File to Subset via ROI**

Select Input File:  
L5117041\_04319900722\_870.TIF.ovr

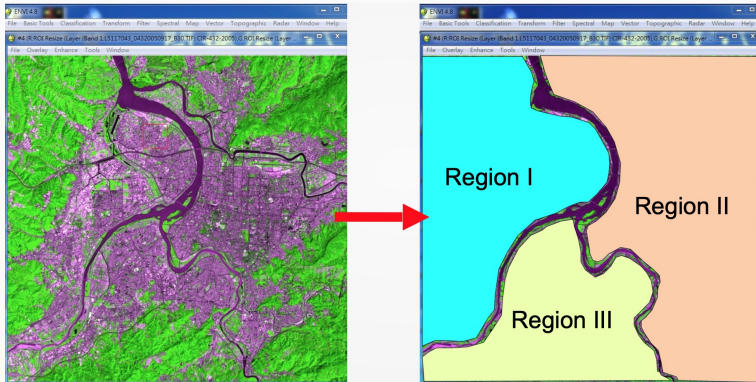
File Information:  
File: D:\Landsat-1990-07-22\CI-R-432.ovr  
Date: 4/21/13 1:13:00  
Size: (Unkwn) 25,862,000 bytes  
File Type: TIFF  
Sensor Type: HSI/pan  
Byte Order: Host (Little)  
Precision: None  
Width: 4051  
Height: 3561  
Upper Left Corner: L1  
Description: TIFF File Imported into ENVI [Wed Apr 24 09:38:13 2013]

# Subset Data via ROI

The screenshot displays the ENVI GIS interface with several key components:

- Main Map Window:** Shows a satellite image of Taipei, Taiwan, with a red ROI box highlighting a specific urban area.
- File -> Available Bands List:** Lists available bands for the selected file, including CIR-432-2005, L5117043\_0420000917\_B00.tif, and CIR-432.ave.
- Select Input File to Subset via ROI:** A dialog box for selecting the input file to be subsetted. It shows a list of files and a 'Select By File' button.
- Spatial Subset via ROI Parameters:** A dialog box for defining the ROI parameters. It shows 'Region #1' selected with 101582 points and a 'Mask points outside of ROI?' checkbox.
- File Explorer:** Shows the file structure, including the 'ROI-Taipei.roi' file.

# Regional Division of Taipei City



# Statistics of Change Detection: Process

1. Classification menu

2. Available Bands List

3. Select Initial State Image

4. Final State Image

5. Define Equivalent Classes

6. Define Pixel Sizes for Area Statistics

7. Change Detection Statistics Output

Process workflow:

- Change detection statistics
- Setting options of process
- Choice of 'Initial Stage' image
- Choice of 'Final Stage' Image
- Defining equivalent classes
- Defining pixel size for area statistics
- Change detection statistics output

# Post-Classification Data Processing

ENVI 4.8

File Basic Tools Classification Transform Filter Spectral Map Vector Topographic Radar

- Resize Data (Spatial/Spectral)
- Subset Data via ROIs
- Rotate/Flip Data
- Layer Stacking
- Convert Data (BSQ, BIL, BIP)
- Stretch Data
- Statistics
  - Compute Global Spatial Statistics
  - Compute Local Spatial Statistics
- Change Detection
- Measurement Tool
- Band Math
- Spectral Math
- Segmentation Image
- Region Of Interest
  - Mosaicking
  - Masking
  - Preprocessing

Local Spatial Statistics Input File

Select Input File:

- 1990-local-statis\_cod\_gi
- 1990-local-stategy\_s
- 1990-local-stmonan\_1
- kmeans1990-ROI
- 2005-543-ROI
- 1990-543-ROI
- kmeans1990-ROI
- 2005-543
- 1990-543

File Information:

File: D:\landlab\1990-07-22\A\_SUPERVISED-CLA  
Date: 703 x 670 x 1 [RGB]  
Size: [Byte] 471,010 bytes  
File Type : ENVI Classification  
Sensor Type: Unknown  
Byte Order: Host (Little)  
Projection: UTM, Zone 51 North  
Pixel : 30 Meters  
Datum : WGS-84  
Wavelength: None  
Upper Left Corner: 3332,1409  
Description: File Resize Result, x  
resize factor: 1.000000, y resize  
factor: 1.000000, [Thu Apr 25  
13:00:18 2013]

Local Spatial Statistics Parameters

Neighborhood Rule: Rook's Case

Calculate Statistics at Multiple Ranges

Select Maximum Lag (Pixel): 2

Include Intermediate Lags

Output Local Moran's I (Clustering)

Output Local Getis-Ord Gi\* (Hot Spots)

Output Local Geary's C (Variability)

Output Result to: File Memory

Enter Output Root Name: Choose

190-07-22\A\_SUPERVISED-CLASS\1990-local-stat

OK Cancel Help

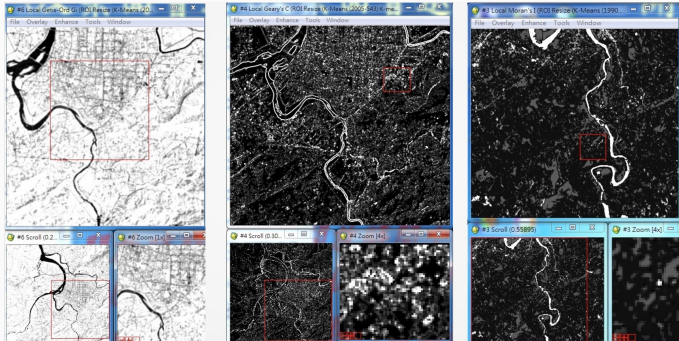
1990 TIF, G.Layer (Band 1 L5117043...)

points (62.35%) (33,303,308 0000 Meters)  
points (15.58%) (23,326,200 0000 Meters)

Unclassified

Un	Max	Mean	Stdev
0	0	0.000000	0.000000

DN	Npts	Total	Percent	Acc	Pct
0	0	0	-NaN	-NaN	
1	0	0	-NaN	-NaN	
2	0	0	-NaN	-NaN	
3	0	0	-NaN	-NaN	
4	0	0	-NaN	-NaN	
5	0	0	-NaN	-NaN	
6	0	0	-NaN	-NaN	

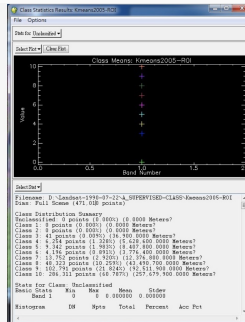
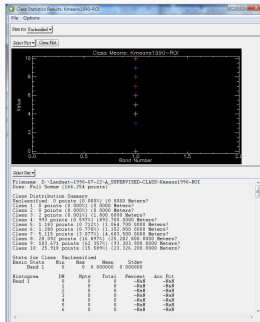


- Left: **Getis Ord G statistics** - measures concentration of the emergency values (highest or lowest) for the land cover classes
- Center: **Geary statistics** - measures spatial dependance and autocorrelation of pixels.
- Right: **Moran statistics** - measures spatial features similarity values based on pixels location and values



# Computed Areas of the Land Cover Types

Results: ROI has changes in land cover classes:



1. class "urban areas" increased from 16.9% in 1990 to 21.8% in 2005
2. class "urban vegetation" decreased from 3.1% in 1990 to 2.9% in 2005
3. class "forests" decreased from 62.4% in 1990 to 60.8% in 2005
4. class "grasslands" decreased from 15.6% in 1990 to 10.3% in 2005

## Results

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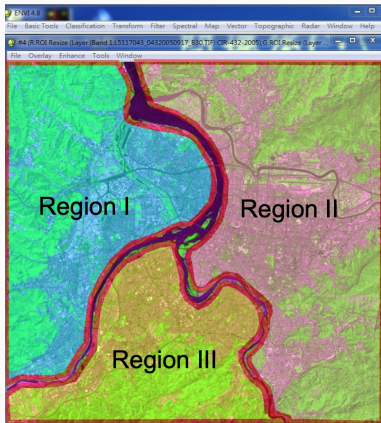
## Results: Regions I, II and III

Three regions of Taipei have differences in the land cover types:

	1990, %	2005, %
Region I: "urban areas"	17,1	21,9
Region I: "urban vegetation"	5,7	4,1
Region I: "forests"	19,8	18,6
Region I: "grasslands"	21,4	18,3
Region II: "urban areas"	79,3	83,2
Region II: "urban vegetation"	4,3	5,2
Region II: "forests"	32,7	31,8
Region II: "grasslands"	15,9	14,7
Region III: "urban areas"	24,3	38,2
Region III: "urban vegetation"	3,7	4,3
Region III: "forests"	42,4	41,8
Region III: "grasslands"	13,8	12,1

## Conclusions

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## Comparison of regions I, II and III:

- Region I: located on the left bank of Tamsui river, agricultural area. It has significant changes in the land cover types since 1990s.
- Region II is the core, old city area is the most stable region. It has the least changes: this area is already industrialized for a long time.
- Region III is an area located southwards from the core city. It has undergone notable changes caused by intensive relocation of the population to the Taipei area after 1980s. This is regions is dynamically developing since 1990s.

## Discussion

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- Spatial analysis performed by ENVI GIS enabled to process satellite images for urban studies.
- Spatio-temporal analysis was applied to Landsat TM images taken at 1990 and 2005:
- Built-in functions of the mathematical K-means algorithm enabled to classify Landsat TM images and to derive information on land cover types.
- Image classification was used to analyze land cover changes in Taipei which includes built-up areas and natural green areas.
- Results of image processing and spatial analysis show changes in structure, shape and configuration of urban landscapes in Taipei since 1990
- Areas occupied by human activities increased, while natural landscapes undergone modifications.
- Changes in urban landscapes of Taipei are caused by the increased relocation of population, urbanization and occupied lands for urban needs.

**Thanks**

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## Bibliography

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# Bibliography

Author's publications on Cartography, Mapping, Geography, Environment, GIS and Landscape Studies:

- 1 S. Gauger, G. Kuhn, K. Gohl, T. Feigl, P. Lemenkova, and C. Hillenbrand, "Swath-bathymetric mapping", *The expedition ANTARKTIS-XXIII/4 of the Res. Vessel 'Polarstern' in 2006. Berichte zur Polar- und Meeresforschung // Rep. on Polar and Marine Res.* **557**, edited by K. Gohl, 38–45, ISSN: 1618-3193 (2007), <https://www.coldregions.org/vufind/Record/288392>, In English Ant. Acc. No.: 85104. CRREL Acc. No.: 63000887; illus., incl. sketch maps.
- 2 K. Gohl, G. Eagles, G. B. Udintsev, R. D. Larter, G. Uenzelmann-Neben, H. W. Schenke, P. Lemenkova, J. Grobys, N. Parsieglä, P. Schlueter, T. Deen, G. Kuhn, and C. D. Hillenbrand, "Tectonic and Sedimentary Processes of the West Antarctic Margin of the Amundsen Sea Embayment and Pine Island Bay", in *2<sup>nd</sup> Open Science Conference 29<sup>th</sup> SCAR on 'Antarctica in the Earth System'* (2006), <https://www.scar.org/events/>.
- 3 K. Gohl, G. Uenzelmann-Neben, G. Eagles, A. Fahl, T. Feigl, J. Grobys, J. Just, V. Leinweber, N. Lensch, C. Mayr, N. Parsieglä, N. Rackebandt, P. Schloter, S. Suckro, K. Zimmermann, S. Gauger, H. Bohlmann, G. L. Netzeband, and P. Lemenkova, *Crustal and Sedimentary Structures and Geodynamic Evolution of the West Antarctic Continental Margin and Pine Island Bay*, (Bremerhaven, Germany, 2006), [https://epic.Alfred%20Wegener%20Institute.de/29852/1/PE\\_75.pdf](https://epic.Alfred%20Wegener%20Institute.de/29852/1/PE_75.pdf).
- 4 M. Klaučo, B. Gregorová, U. Stankov, V. Marković, and P. Lemenkova, "Determination of ecological significance based on geostatistical assessment: a case study from the Slovak Natura 2000 protected area", *Central European Journal of Geosciences* **5**, 28–42, ISSN: 1896-1517 (2013), <https://www.degruyter.com/view/j/geo.2013.5.issue-1/s13533-012-0120-0/s13533-012-0120-0.xml?format=INT>.
- 5 G. Kuhn, C. Hass, M. Kober, M. Petitot, T. Feigl, C. D. Hillenbrand, S. Kruger, M. Forwick, S. Gauger, and P. Lemenkova, *The response of quaternary climatic cycles in the South-East Pacific: development of the opal belt and dynamics behavior of the West Antarctic ice sheet*, (Bremerhaven, Germany, 2006), [https://epic.Alfred%20Wegener%20Institute.de/29852/1/PE\\_75.pdf](https://epic.Alfred%20Wegener%20Institute.de/29852/1/PE_75.pdf).
- 6 P. Lemenkova, "Monitoring changes in agricultural landscapes of Central Europe, Hungary: application of ILWIS GIS for image processing", in *Geoinformatics: theoretical and applied aspects*, Proceedings of 12th International Conference (2013).
- 7 P. Lemenkova, "Geospatial Technology for Land Cover Analysis", *Middle East and Africa (MEA) Geospatial Digest* (2013), <https://www.geospatialworld.net/article/geospatial-technology-for-land-cover-analysis/>, e-magazine (periodical).
- 8 P. Lemenkova, "Impacts of Climate Change on Landscapes in Central Europe, Hungary", in *Current Problems of Ecology, Ecological monitoring and management of natural protection*, Proceedings of 8th International Conference, Vol. 2 (2012), pp. 134–136, <https://elib.grsu.by/katalog/173327-393652.pdf>.

- 9 P. Lemenkova, "Water Supply and Usage in Central Asia, Tian Shan Basin", in Civil eng., architecture & environmental protection, Phidac-2012, Proceedings of the 4th International Symposium for Doctoral studies in the Fields of Civil Engineering, Architecture & Environmental Protection, edited by Z. Grdic and G. Toplicic-Curcic (Sept. 2012), pp. 331–338, ISBN: 978-86-88601-05-4.
- 10 P. Lemenkova, "Seagrass Mapping and Monitoring Along the Coasts of Crete, Greece", M.Sc. Thesis (University of Twente, Faculty of Earth Observation and Geoinformation (ITC), Enschede, Netherlands, Mar. 8, 2011), 158 pp., <https://thesiscommons.org/p4h9v>.
- 11 P. Lemenkova, "Using ArcGIS in Teaching Geosciences", Russian, B.Sc. Thesis (Lomonosov Moscow State University, Faculty of Educational Studies, Moscow, Russia, June 5, 2007), 58 pp., <https://thesiscommons.org/nmjgz>.
- 12 P. Lemenkova, "Geoecological Mapping of the Barents and Pechora Seas", Russian, B.Sc. Thesis (Lomonosov Moscow State University, Faculty of Geography, Department of Cartography and Geoinformatics, Moscow, Russia, May 18, 2004), 78 pp., <https://thesiscommons.org/bvwcr>.
- 13 P. Lemenkova, *Ecological and Geographical Mapping of the Baltic Sea Region in the Gulf of Finland*, Russian, Moscow, Russia: Lomonosov Moscow State University, Mar. 30, 2002, <https://zenodo.org/record/2574447>, Term Paper.
- 14 P. Lemenkova and I. Elek, "Clustering Algorithm in ILWIS GIS for Classification of Landsat TM Scenes: a Case Study of Mecsek Hills Region, Hungary", in *Geosciences and environment, Near-surface geophysics, Proceedings 3rd International Conference*, edited by S. Komatina-Petrovic (2012).
- 15 P. Lemenkova, B. Forbes, and T. Kumpula, "Mapping Land Cover Changes Using Landsat TM: A Case Study of Yamal Ecosystems, Arctic Russia", in *Geoinformatics: theoretical and applied aspects, Proceedings of the 11th International Conference (2012)*, <https://elibrary.ru/item.asp?id=24527736>.
- 16 H. W. Schenke and P. Lemenkova, "Zur Frage der Meeresboden-Kartographie: Die Nutzung von AutoTrace Digitizer für die Vektorisierung der Bathymetrischen Daten in der Petschora-See", *German, Hydrographische Nachrichten* **25**, 16–21, ISSN: 0934-7747 (2008).
- 17 I. Suetova, L. Ushakova, and P. Lemenkova, "Geoecological Mapping of the Barents Sea Using GIS", in *Digital cartography & gis for sustainable development of territories, Proceedings of the International Cartographic Conference (2005)*, <https://icaci.org/icc2005/>.
- 18 I. Suetova, L. Ushakova, and P. Lemenkova, "Geoinformation mapping of the Barents and Pechora Seas", *Geography and Natural Resources* **4**, edited by V. A. Snytko, 138–142, ISSN: 1875-3728 (2005), [http://www.izdatgeo.ru/journal.php?action=output&id=3&lang\\_num=2&id\\_dop=68](http://www.izdatgeo.ru/journal.php?action=output&id=3&lang_num=2&id_dop=68).