



StratAG

Strategic Research in Advanced Geotechnologies
Taighde Straitéiseach sna hArd-Gheoteicneolaíochtaí



NUI MAYNOOTH
Ollscoil na hÉireann Má Nuad



National Centre for Geocomputation
An tIonad Náisiúnta Geoiríomhaireachta

Improving seabed mapping from marine acoustic data

Dr Urška Demšar
NCG, NUIM

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Uncovering Information in Large Marine Acoustic Data Sets with Spatial and Statistical Analysis

Research Team

Prof Stewart Fotheringham,
Dr Sean McLoone,
Dr Urška Demšar,
Dr Paul Harris,
Dr Peter Hung
Kazi Ishtiak Ahmed,
Helen Caughey

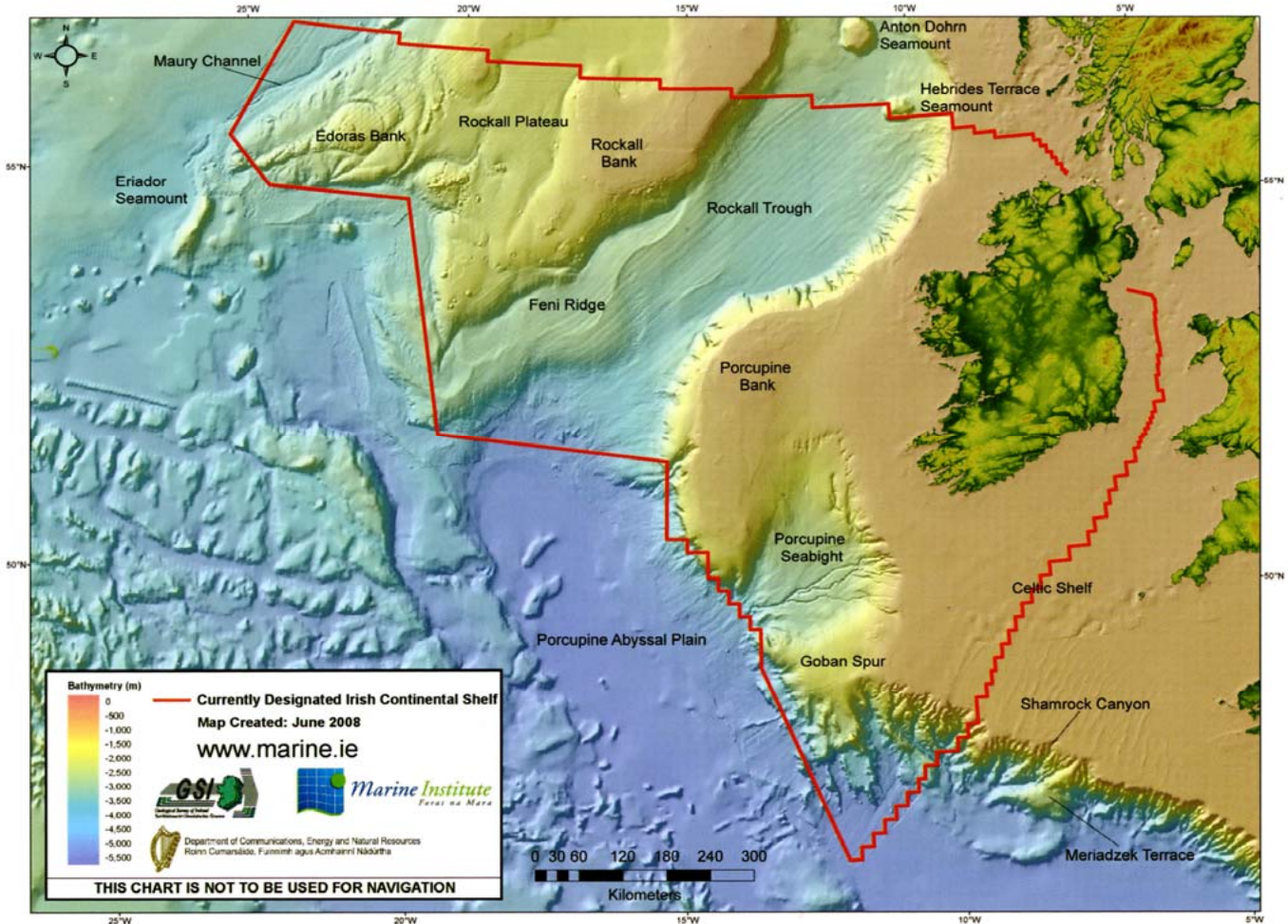


+



Xavier Monteys,
Ronan O'Toole

The Real Map of Ireland

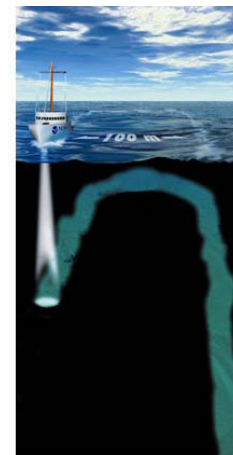
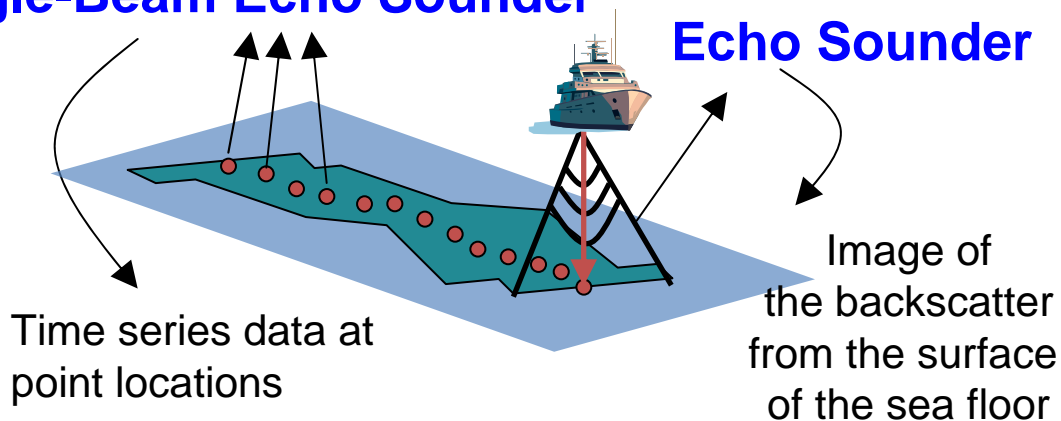


Knowledge discovery from shallow water MBES data & SBES data using Geovisual Analytics

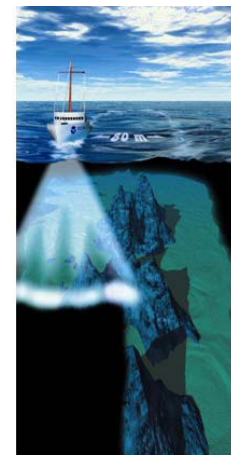
PhD project, Kazi Isthiak Ahmed, 2009-2011, supervisor Dr Urška Demšar
GSI: Xavier Monteys

Single-Beam Echo Sounder

Multi-Beam Echo Sounder



Single Beam Echo Sounder Surveys



Multibeam Full Bottom Coverage

Research topics:

- Exploring complexity of feature-based methodology for seabed type classification from MBES backscatter data and comparison with an alternative visual classification method (Self-Organising Map)

MBES

- Using a time-series data mining approach for seabed type classification from SBES data

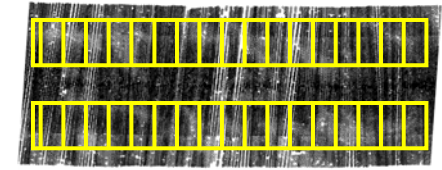
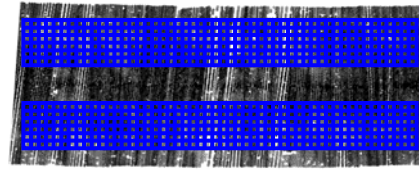
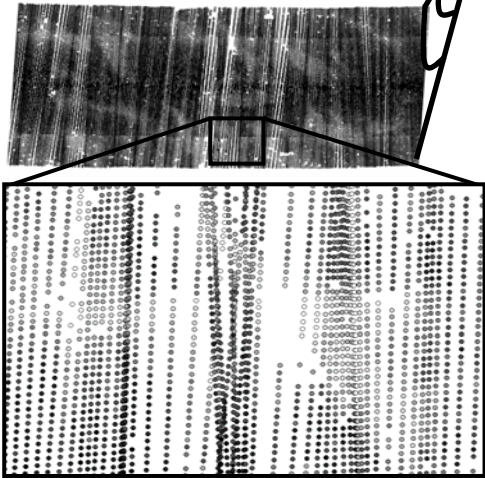
SBES

- Combine SBES and MBES data via their spatial location

MBES + SBES

MBES raw data – backscatter measurements

Image compensation to remove effects of sonar angle and range



Interpolated acoustic image (pixels)

Interpolated acoustic image (patches)

Feature-based methodology

Full Feature Vectors (FFVs, statistical descriptors) for each patch

	ffv1	ffv2	ffv3	...	ffv132
patch1				...	
patch2				...	
patch3				...	
...	

Automatic classes

Clustering

Space of three main principal components

Dimensionality Reduction - PCA

SOM-defined classes

Comparison

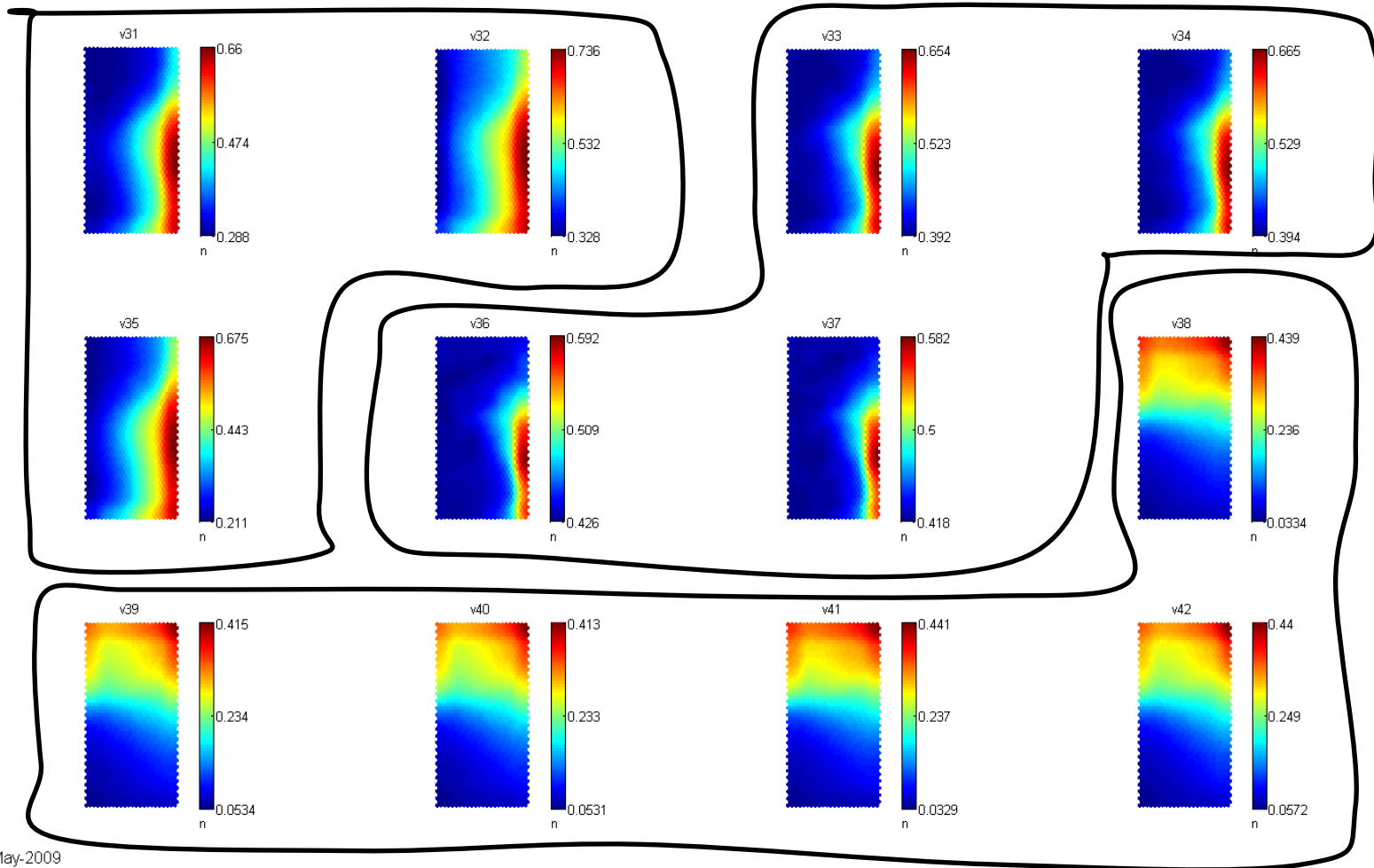
Similarity of data objects (patches)

SOM

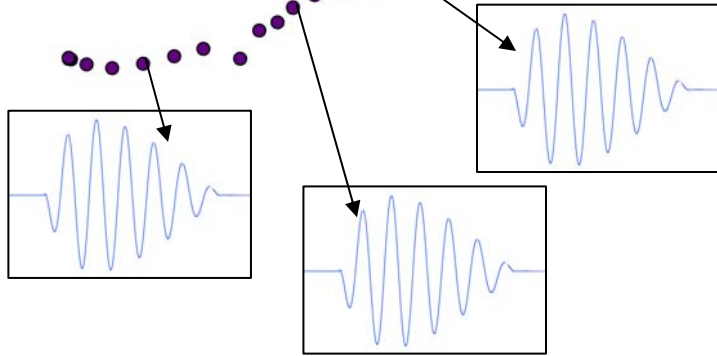
Similarity and potential redundancy of attributes (features)

Geovisual Analytical exploration

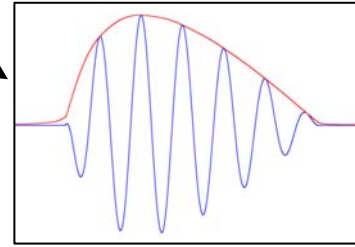
Visual attribute clustering with component planes visualisation of a Self-Organising Map



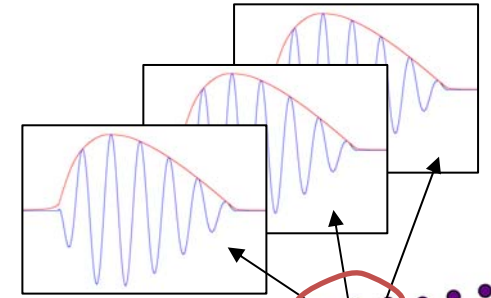
SBES backscatter measurements = full-waveform time series at each location = **Echos**



Compensation to remove effects of depth and slope



Echo envelope at each location



Stacking of nearby envelopes

Statistical Classification, feature-based

Acoustic classes in 3D space

Clustering in 3D space

Space of three main principal components

Dimensionality Reduction – PCA

Calculate features (statistical descriptors) for each stack of envelopes, typically between 100-200 features (dimensions)

	f1	f2	f3	...	fn
stack 1				...	
stack 2				...	
stack 3				...	
...	

Time series data mining - clustering

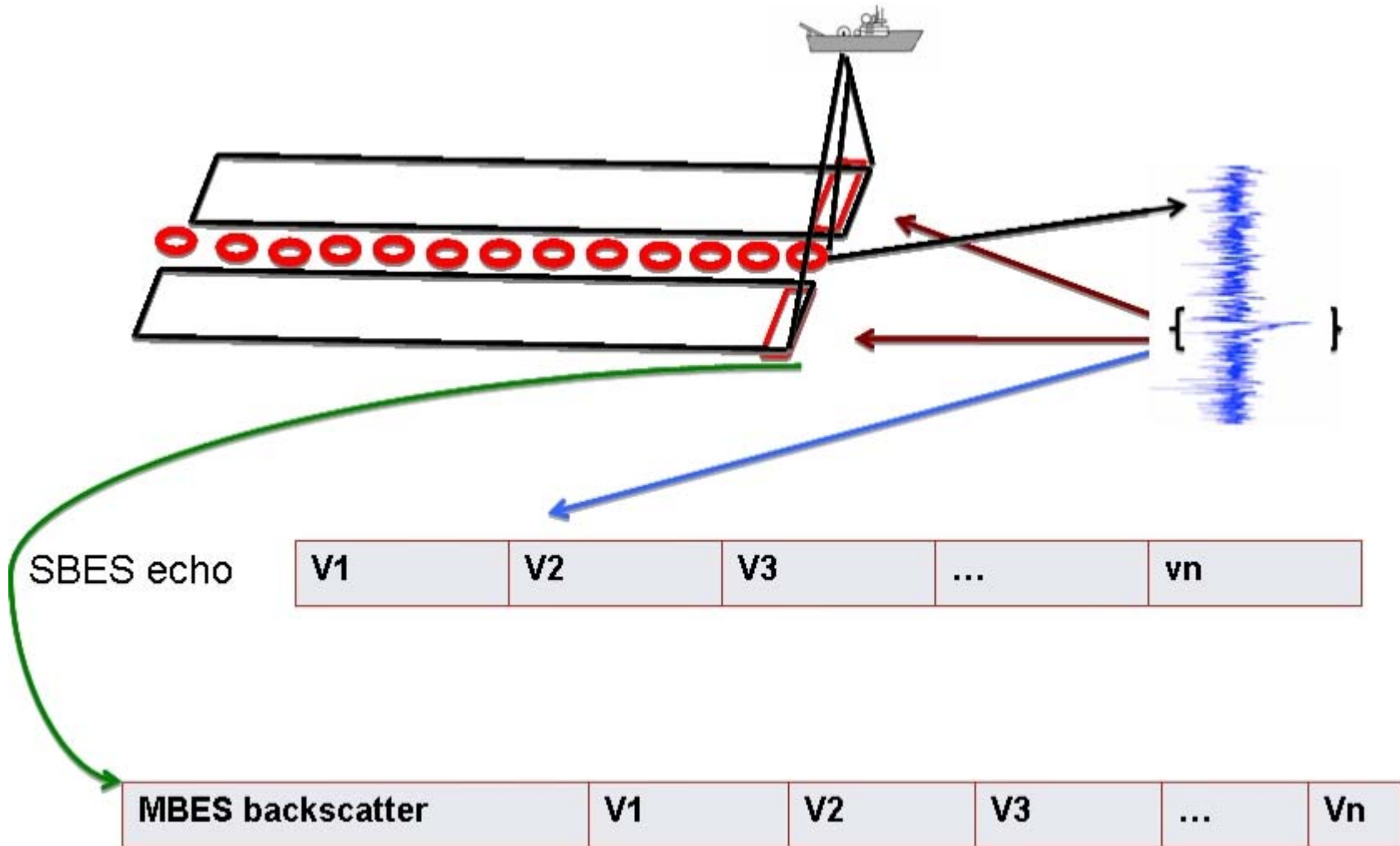
Computational

Similar echoes = similar seabed type

Visual

Acoustic classes defined in original time series space

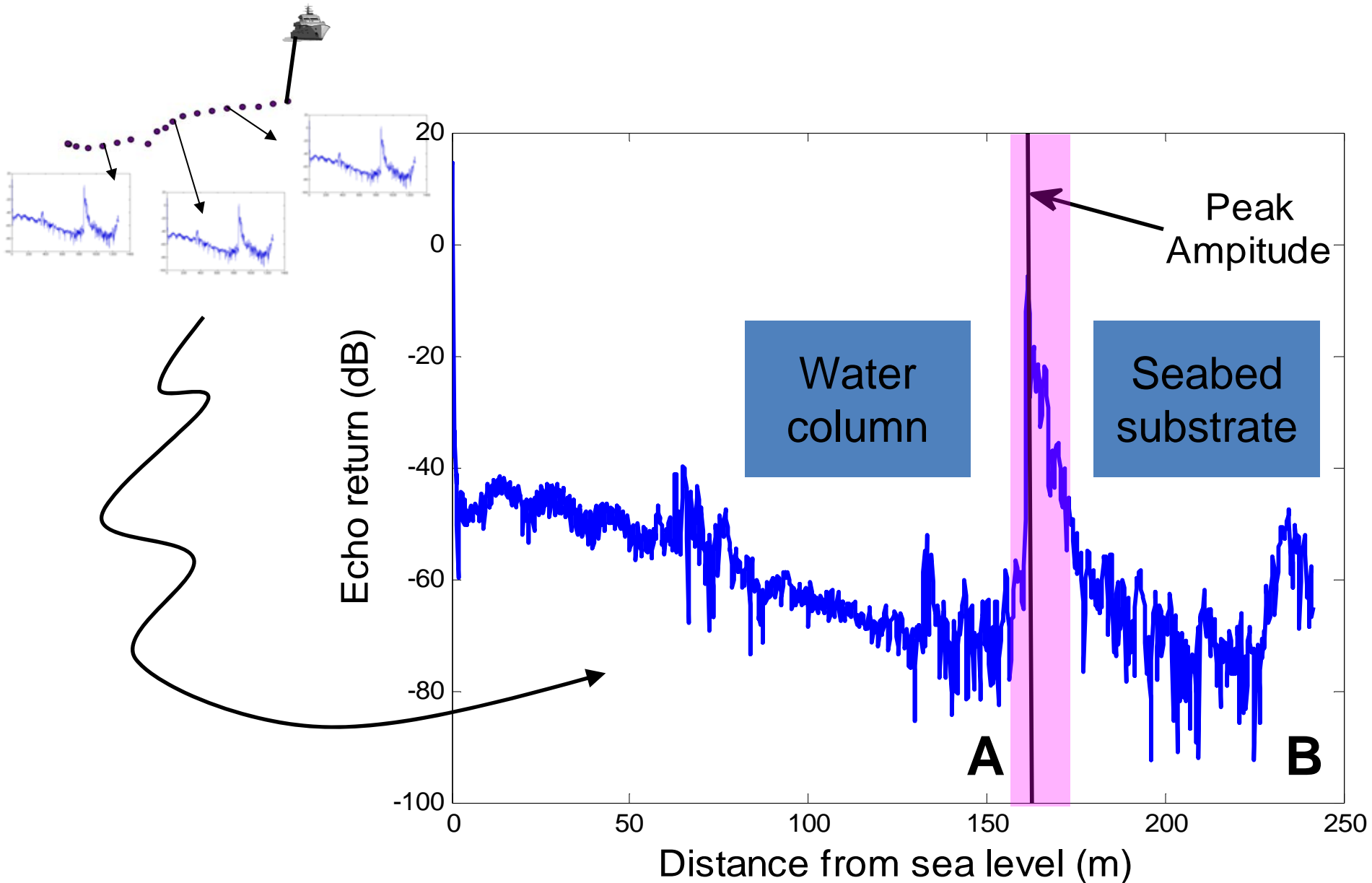
Combine SBES and MBES data via their spatial location

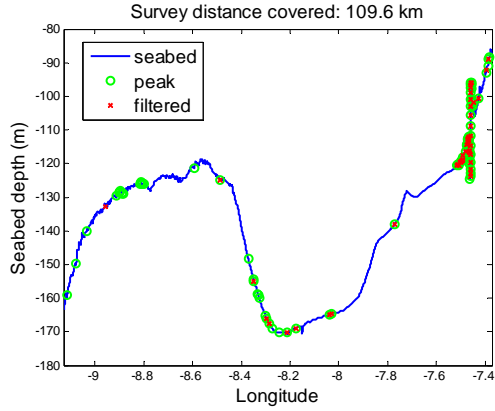
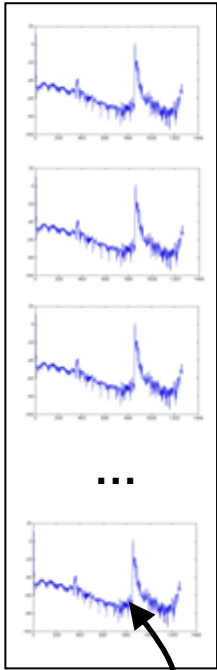


Use combined data for seabed type classification with visual and computational classification methods

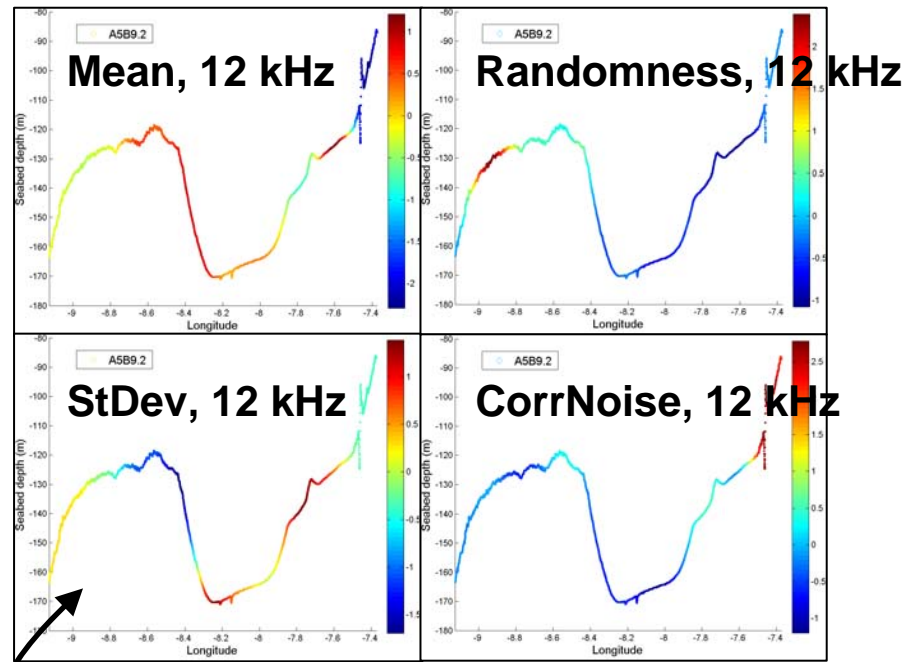
Seabed type classification from SBES data

Research project, Dr Peter Hung, Dr Seán McLoone, GSI: Xavier Monteys





Bathymetric filtering to determine exact depth



Echo data collection

Data cleanup and sampling

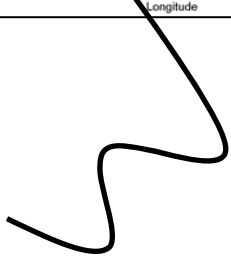
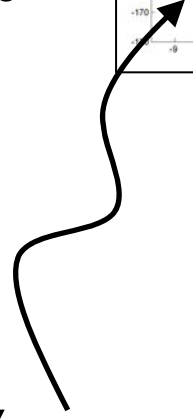
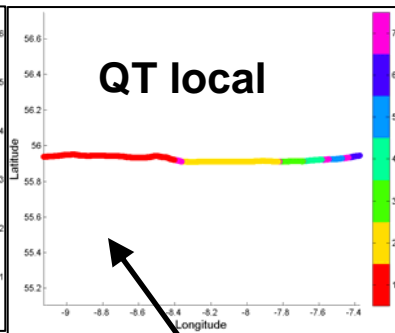
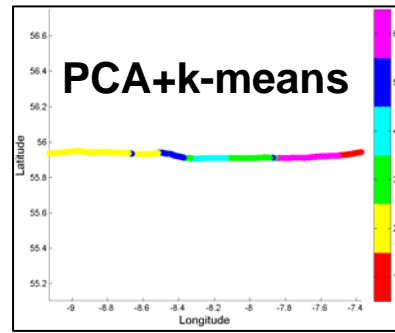
Feature extraction

Feature selection

Clustering

Quality check

Poster



Improving seabed type classification from MBES backscatter data in deep waters (200-5000m)

Research project – all StratAG+GSI members of the team

MBES backscatter data from zone 3, depth 200-5000m

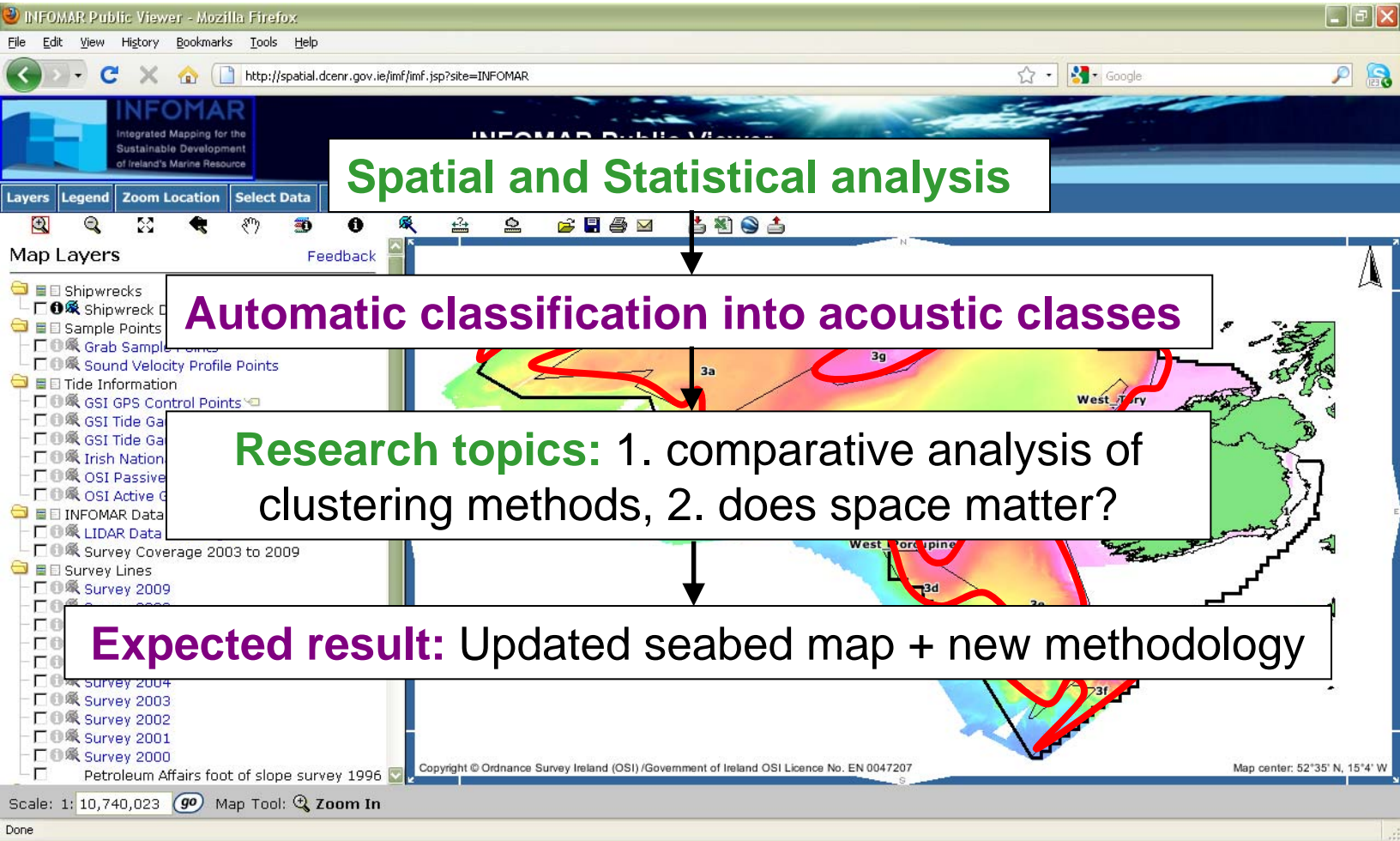
3 pulse lengths

3 years

- 2000
- 2001
- 2002

5 features

- Mean
- Quantile
- Pace
- Contrast
- StDev



Automatic classification into acoustic classes

Research topics: 1. comparative analysis of clustering methods, 2. does space matter?

Expected result: Updated seabed map + new methodology

Data characteristics and related research challenges

Large and complex dataset

Depths 200-5000m

5 statistical descriptors and over 1 million entries

Data processing is a complex procedure

Spatial relation not always captured

Extremely noisy backscatters

Still lacking standardized procedures

Expensive and lack of funds

More focus on the shallow waters

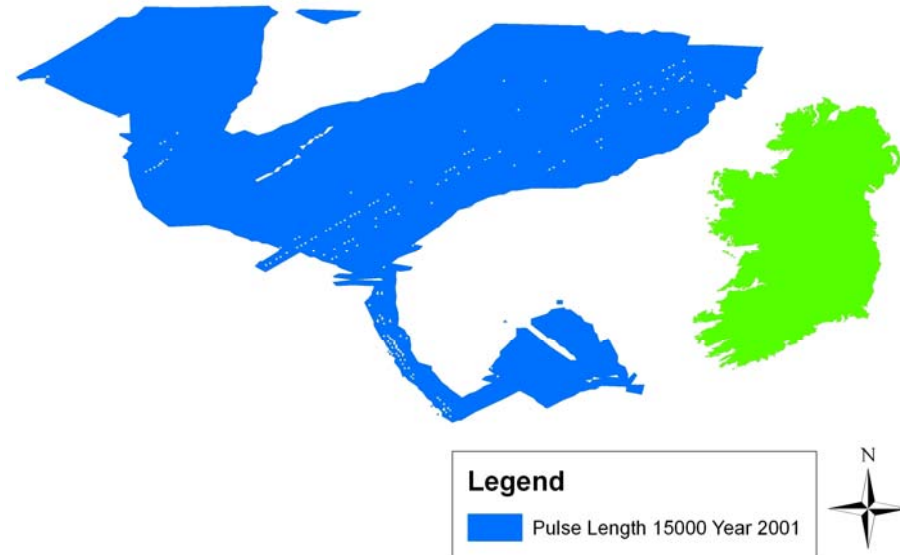
Limited availability of ground truth data

Size of each patch is at least 10,000 times larger than GT sampling techniques

Incoherent correspondence

No ground truth available for this project

Deep water MBES
backscatter dataset



Research question 1: Comparative analysis of clustering methods

Five clustering algorithms

PCA + k-means

De facto "standard"

Results depend on initial choice of cluster centres

Can be trapped in local minima of intra-cluster variance

Does not recognise non-convex, non-isotropic, non-globular clusters

Spectral clustering

Graph-based: optimal partitioning of similarity graph in attribute space

Fuzzy c-means clustering (FCM)

Allows overlap between classes

Geologically, class boundaries are rarely crisp

Quality threshold local clustering (QT local)

Density-based: clusters defined as dense areas in attribute space

Capable of recognising irregular shaped samples

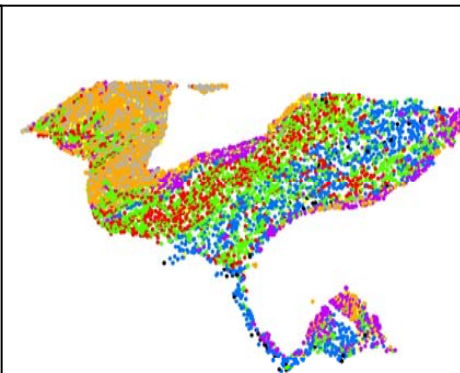
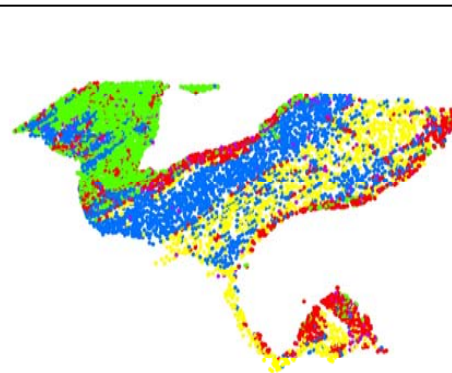
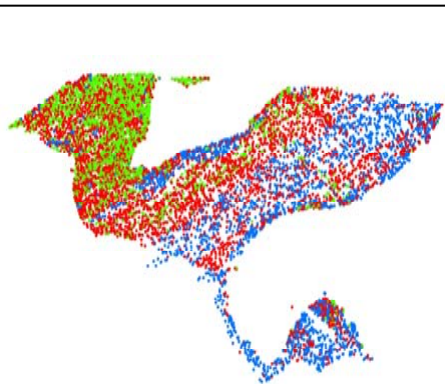
Maximum separation clustering (MSC)

3 clusters

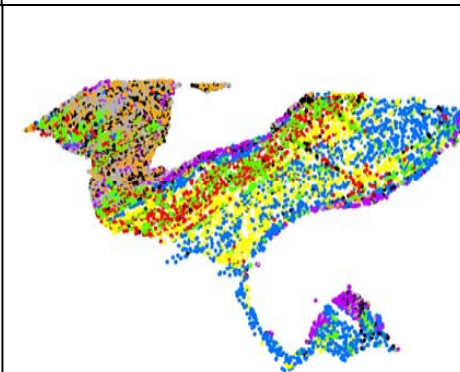
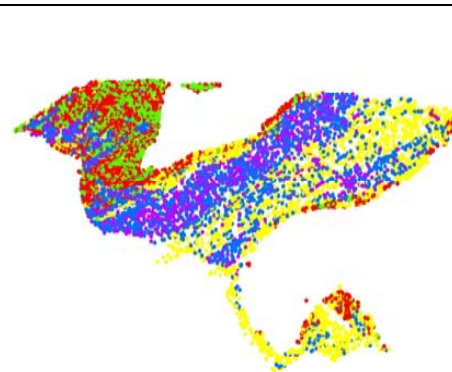
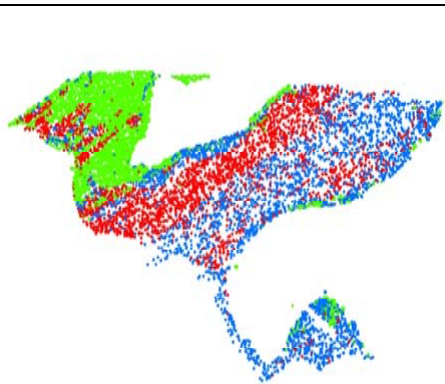
5 clusters

8 clusters

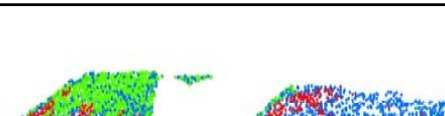
PCA +
k-means



Spectral
clustering



QT-local
clustering



No ground truth data available due to depth (200-5000m).



Spatial and non-spatial comparisons between methods.

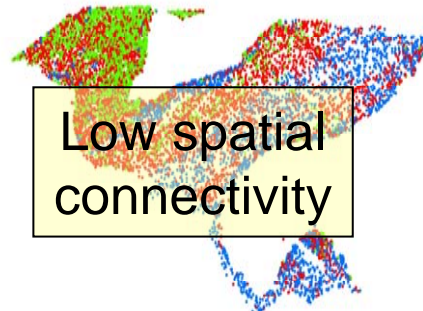
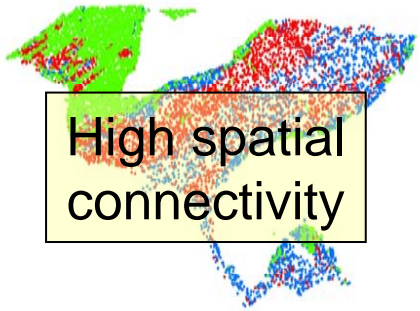
Not shown:
FCM,
MSC

Spatial comparison of clustering methods

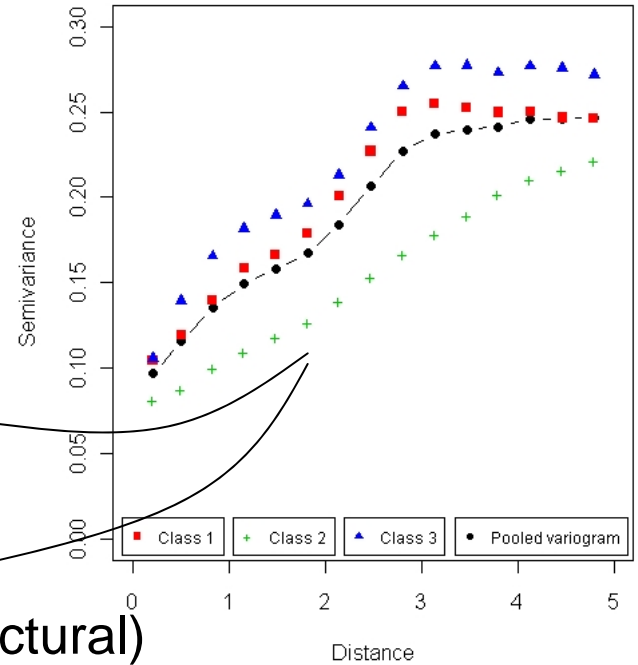
Determining the level of spatial connectivity for 3 – 12 clusters

Less speckleness

More speckleness

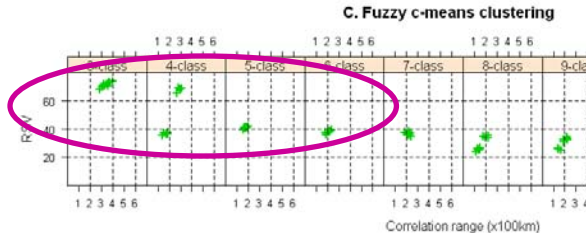
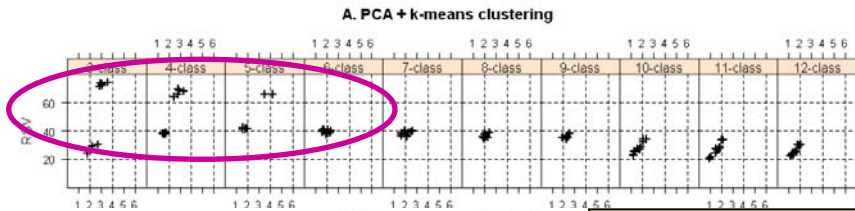


A. Estimated indicator variograms

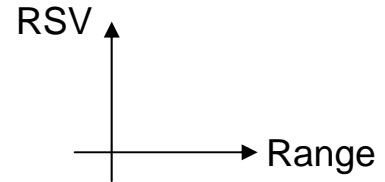


Range = distance at which the space still has an effect on the variance

Relative Structural Variability (RSV) = structural variance / total variance (nugget + structural)



Trellis plots



Spatial connectivity is strongest for PCA+k-means, Spectral, and Fuzzy c-means clustering when the cluster numbers is small.

Non-spatial comparison of clustering methods

Satellite/Aerial Remote Sensing

Calculations for 3 and 8 clusters

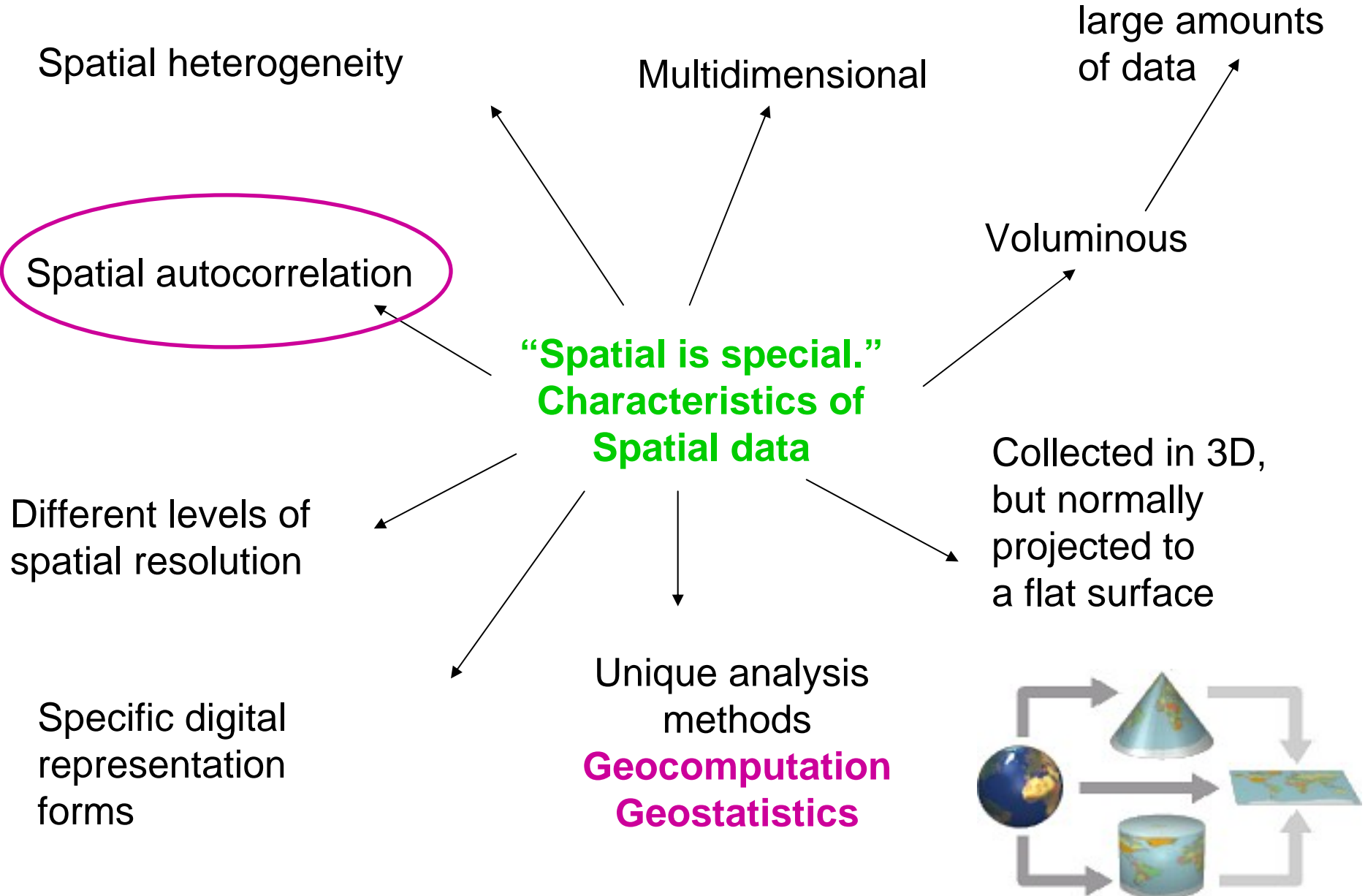
		Confusion matrices				Kappa	Overall accuracy (%)
Spectral	PCA+k-means	1	2	3	4	0.5759	71.23
	1	2322	1663	793	4778		
	2	421	2330	0	2751		
	3	0	0	2471	2471		
		2743	3993	3264	10000		
Fuzzy	PCA+k-means	1	2	3	4	0.445	76.36
	1	2872	1595	311	4778		
	2	364	2387	0	2751		
QTL						0.393	53.38
MSC	PCA+k-means	1	2	3	4	0.2498	45.71
	1	698	89	3991	4778		
	2	386	1402	963	2751		
	3	0	0	2471	2471		
		1084	1491	7425	10000		

PCA+k-means, spectral and fuzzy c-means clustering had best agreement for 3 clusters, but less for 8 clusters.

QT-local/MSC different from the other three methods for both 3 and 8 clusters.

Research question 2: Does space matter for seabed type classification?

Why are spatial data different?



Spatial autocorrelation (spatial dependency)

tendency of data objects at some location in space to be related

1st law of geography (Tobler's law):
Everything is related to everything else, but nearby things are more related than distant things.

Often inappropriate to use the traditional analysis methods (statistics, data mining, etc.) for spatial data.

The two basic assumptions may not be valid: spatial data are not independently generated, nor are they identically distributed.

Special analysis methods: spatial analysis, geocomputation, geostatistics

Current research topics:

- What is the level of spatial autocorrelation in MBES backscatter?
- evaluating **spatially-aware adaptations** to all five clustering algorithms and looking at other spatially-aware classification methods.



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Thank you!

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