Approaches to supporting coverages and multidimensional arrays required by Annex II and III

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Safe Software

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Agenda

- Use of coverages in INSPIRE
- Data model representations
- Read and Extract tools
- Transform approaches
- Application examples
- Challenges & lessons
- Upcoming developments
What is FME?

FME transforms data to use and share.

- Convert data
- Transform data
- Share data
- Integrate data
- Validate data
- And more
FME’s power for data extraction is unparalleled with support for 400+ data formats & services.

- Reads vector, raster, point cloud, non-spatial SQL databases, no-SQL databases, web sources: GML, XML, JSON, API’s, cloud.
FME Bridges the Gap

Vendor Systems and Formats

Open Standards

Open Source
FME - INSPIRE Life Cycle Support

Evaluation
Data assessment

Publication
WxS, GML, PDF, KML

Assembly
Formats, Joins

Validation
QA, XSD, values

Transformation
schema, geometry

Write
INSPIRE GML
Key Raster Formats

Orthophotos:
- GeoTIFF, JPEG2000, ECW
- OGC Services: WMS, WCS
- Cloud based satellite imagery distribution: Sentinal, Planet, Urthcast (near daily)

Elevation: GeoTIFF, ESRI ASCII Grid, DTED

Model / Sensor: NetCDF, web services: JSON, XML, text, HTML tables
Raster Extraction Tools

- Data suitability – Data Inspector
- Read
  - Format readers: Raster, OGC, Cloud readers
  - FeatureReader – each record triggers (automation)
  - Web sources – almost any format can accept a URL
    - ImageFetcher, HTTPCaller
- Filter
  - Spatial – extents: Clipper, SpatialRelator
  - Attribute – range: Tester, RangeFilter
Workflows: Raster Handling

- Less known capability of FME
- Full range of raster processing tools
- Change raster structure to match destination requirements
- Raster algebra & statistics
- Custom transformers: RasterStatisticsCalculator
- See Transformer Guide & Tutorial: Rasters
Raster Transformations

- Reinterpretation, Resampling
- Tiling, Mosaicking, Nodata
- Reprojection
- Clipping
- Offsetting, scaling
- DEM creation, surface modeling
- 3D raster, draping
- Rasterization, raster value extraction
- Vectorization, RasterToPolygonCoercer
## FME Raster Format List

<table>
<thead>
<tr>
<th>Format</th>
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<tbody>
<tr>
<td>ADRG</td>
<td>GeoTIFF</td>
<td>R Statistical Raster (RDATA)</td>
</tr>
<tr>
<td>ASRP</td>
<td>Golden Software Surfer Binary</td>
<td>RADARSAT-2 XML</td>
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<tr>
<td>Aircom ENTERPRISE</td>
<td>Grid</td>
<td>Shuttle Radar Topography</td>
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<tr>
<td>BMP</td>
<td>Hierarchical Data Format 4</td>
<td>Mission Height</td>
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<tr>
<td>Bathymetric Attributed Grid</td>
<td>(HDF4)</td>
<td>(SRTM HGT)</td>
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<tr>
<td>(BAG)</td>
<td>JPEG</td>
<td>TIFF</td>
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<tr>
<td>CADRG</td>
<td>JPEG 2000</td>
<td>USGS DEM</td>
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<tr>
<td>CDED</td>
<td>Landmark Z-MAP</td>
<td>Vertical Mapper Grid (NGrid)</td>
</tr>
<tr>
<td>DTED</td>
<td>Leica Geosystems ERDAS IMAGINE</td>
<td>Web Map Service</td>
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<tr>
<td>ECW</td>
<td>Leica Geosystems ERDAS RAW</td>
<td>World Meteorological Organization GRIB</td>
</tr>
<tr>
<td>ENVI .hdr RAW Raster</td>
<td>Maptech BSB Nautical Chart</td>
<td>X11 Pixmap (XPM)</td>
</tr>
<tr>
<td>ER Mapper ERS</td>
<td>Marconi PlaNet</td>
<td></td>
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<tr>
<td>ESRI .hdr RAW Raster</td>
<td>MrSID</td>
<td></td>
</tr>
<tr>
<td>ESRI ASCII Grid</td>
<td>NETCDF (reading / writing)</td>
<td></td>
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<tr>
<td>ESRI ArcGIS Binary Grid</td>
<td>NITF</td>
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<tr>
<td>ESRI ArcGIS Image Server</td>
<td>Oracle Spatial GeoRaster</td>
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<tr>
<td>ESRI ArcSDE Raster Catalog</td>
<td>PCI Geomatics Database File</td>
<td></td>
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<tr>
<td>ESRI ArcSDE Raster Map</td>
<td>PNG</td>
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<tr>
<td>ESRI Geodatabase Raster GIF</td>
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Manipulating Bands

Band combining, splitting

Offsetting
Scaling
Affine
Georeferencing
Controlling Interpretation

- Data Type
- Bit Depth
- Data Interpretation
- Importance
- Removing or Resolving Palettes
- RasterInterpretationCoercer
Basic Raster Transformations

- Clipping
- Mosaicking
- No-data values
Raster Cell Manipulation & Algebra

- Raster Cell Calculation
- RasterCellValueReplacer
- RasterCellValueCalculator
- RasterExpressionEvaluator

```
0 0 0 0 0
0 0 7 7 0
0 0 7 7 0
0 0 7 0 0
0 0 0 0 0

0 0 0 0 0
0 0 0 0 0
0 0 3 3 0
0 0 3 3 0
0 0 0 0 0

+ 0 0 0 0 0
0 0 3 3 0
0 0 3 3 0
0 0 3 10 0
0 0 3 10 0
0 0 0 0 0

= 0 0 0 0 0
0 0 7 7 0
0 0 3 3 0
0 0 3 3 0
0 0 0 0 0
```
3D and Raster

- Appearances
- Surfaces, TINs
- Draping
- 2.5D vs 3D

Overlaying:
PointOnRasterOverlay
Raster and Vector Interaction

- Generate DEM and estimate flood areas
  - Raster DEM to flood polygon
  - RasterCellValueReplacer
  - RasterToPolygon
  - Generalization
Workflows: Point Clouds

- Full range of point cloud processing tools
- Clip, reproject, resample
- Manipulate components structure and data types
- Change array structure to match destination requirements
- Point cloud calculations & statistics
- PointCloudStatisticsCalculator
- See Transformer Guide & Tutorial: Rasters
Point Cloud Format Support

** LAS (plus LAZ, zLAS)  
** XYZ  
** ASTM E57  
** Oracle Spatial  
** Pointools POD  
** RIEGL Laser Scan Db  
** Terrasolid TerraScan  
** Z+F LaserControl ZFS  
** Minecraft  
** CARIS Spatial Archive  
** Autodesk ReCap  
** Cesium (in progress)
Transform: Classify, Split, Clip

Read LAS → PointCloudSplitter → Split by classification → @Value(class) → Save POD

PointCloudSplitter Parameters:
- Transformer Name: PointCloudSplitter
- Parameters:
  - Split By: classification
  - Split Type: x, y, z
  - Output Attribute: intensity, color_red, color_green, color_blue
  - Ranges to Keep: color_red, color_green, color_blue
  - Unique Values to Keep: classification, return, number_of_returns
Transform: Merge Values from Raster

Surface modelling
Surface Modelling: Bare Earth
What is a Coverage?

- Values over space and time
- Can be regular or irregular grids
- Usually some form of measurement, weather in situ or remote sensing
- Represented by a domain (extent) and range of values that correspond to that domain
- Often stored as arrays with dimension information defining the space, time and value types
Coverage Examples

- Gridded data
- May be grids of points or raster cells
- Applications:
  - imagery
  - elevation models
  - model outputs, often with time series (precipitation, flood)
  - risk
  - formats: NetCDF, GeoTIFF, GML coverages
Coverage examples: INSPIRE Types

- CoverageByDomainAndRange
- CoverageFunction
- GridFunction
- RectifiedGridCoverage
- ReferenceableGridCoverage
Coverage examples: INSPIRE Themes

- AC-MF: Atmospheric Conditions and Meteorological Features
- EL: Elevation Grid Coverage
- ER: Energy Resources
- GE: Geology
- OF: Ocean Features
- OI: Ortho Imagery
- LC: Land Cover
- NZ: Natural Risk Zones (risk coverage)
- SO: Soils
Workflows: NetCDF to KML

- Read NetCDF dimensions as multiband raster
- RasterBandSplitter to break bands into individual features
- ListIndexer to associate band index value with associated raster geometry
NetCDF to KML: Workspace
NetCDF to KML: Ag Emissions
NetCDF to KML: Ag Emissions
NetCDF to KML: Ag Emissions
Transformation Approaches

- Split arrays: NetCDF to GeoTIFF
- Data model conversion: raster <> arrays
- Read range and domain separately and then combine
Challenges

- GML coverage definition for INSPIRE is too loosely defined – subject to customization via extensions
- Need more guidance as to what type of coverages are most important for us to support
- Lack of easily accessible sample data per theme
- At a minimum this presentation gave us an opportunity to see these challenges and adjust our development to address them
GML Coverage Sample from Finnish Meteorological Institute

<om:result><gmlcov:MultiPointCoverage gml:id="mpcv-1-1">
  <gml:domainSet>
    <gmlcov:SimpleMultiPoint gml:id="mp-1-1" srsName="http://xml.fmi.fi/gml/crs/compoundCRS.php?crs=4258&time=unixtime" srsDimension="3">
      <gmlcov:positions>
        60.09726 19.93481 1461844800
        60.09726 19.93481 1461848400 ...
      </gmlcov:positions></gmlcov:SimpleMultiPoint></gml:domainSet>
  <gml:rangeSet>
    <gml:DataBlock><gml:rangeParameters/>
      <gml:doubleOrNilReasonTupleList>
        4.93 8.53 1010.89 75.46 92.0 8.39 -8.12 -2.15 8.47 13.63 2.91 100.0 2.0
        11.7 24.9 100.0 0.0 0.0 12813444.0 6044484.0 -1445534.13 11573148.0 11462539.0
        4.93 8.81 1010.2 75.02 92.0 8.6 -8.33 -2.11 8.6 13.97 3.07 0.0 1.0 0.0
        0.0 0.0 0.0 0.0 15244839.0 6989885.5 -1743936.5 13769114.0 12932554.0
      </gml:doubleOrNilReasonTupleList></gml:DataBlock>
  </gml:rangeSet>
</gmlcov:MultiPointCoverage></om:result>
GML Coverage to Point Cloud
GML Coverage Viewer

Diagram of GML Coverage Viewer with nodes and connections.
INSPIRE GML Coverage – GML Reader
GML Coverage: Point Cloud
**GML Coverage: Point Cloud**

*Image of a software interface with a list of properties and their values.*
INSPIRE Web Services

1. OGC WMS: 1.0, 1.1, 1.3
2. OGC WFS: 1.0, 1.1, 2.0
3. Atom/RSS
4. ArcGIS Online
5. REST
6. JSON, GeoJSON
7. Amazon Web Services
XML Reading

- Metadata
- GML embedded in XML
- Leveraging web services and content: RSS, XML streams, HTML
- Use metadata to drive workflow automation
  - Parse GetCapabilities to compose GetFeature requests
British Geological Survey
Demonstration WCS

http://ogcdev.bgs.ac.uk/ogcclient/WCS/GetCoverage_v2_0_1.html
WCS GetCapabilities Response

<?xml version="1.0" encoding="UTF-8"?>
<wcs:Capabilities xmlns:inspire_dls =
"http://inspire.ec.europa.eu/schemas/inspire_dls/1.0" xmlns:inspire_common =
"http://inspire.ec.europa.eu/schemas/common/1.0"
xlns:gmlcov="http://www.opengis.net/gmlcov/1.0"
xlns:gml="http://www.opengis.net/gml/3.2"
xlns:wcs="http://www.opengis.net/wcs/2.0">

...<wcs:Contents>
  <wcs:CoverageSummary>
    <wcs:CoverageId>OneGDev__CentralMed-MCol</wcs:CoverageId>
    <wcs:CoverageSubtype>RectifiedGridCoverage</wcs:CoverageSubtype>
  </wcs:CoverageSummary>
  <wcs:CoverageSummary>
    <wcs:CoverageId>OneGDev__AegeanLevantineSeas-MCol</wcs:CoverageId>
    <wcs:CoverageSubtype>RectifiedGridCoverage</wcs:CoverageSubtype>
  </wcs:CoverageSummary>
</wcs:Contents>
</wcs:Capabilities>
GetCoverage Response
Consuming INSPIRE data and Services

- INSPIRE services should be results oriented and driven by user requirements

- FME takes the pain out of reading and leveraging complex GML, XML and web services

- Data Inspector makes it easy
  - Visualize all data types: 2D / 3D, vector / raster, non-spatial / complex geometries
  - Consume directly from URLs or web services
  - Inspect complex data models and geometries
Your INSPIRE Viewer: Data Inspector

Read any GML
Complex Attributes: Land Cover Units
Three Ways to use FME

FME Desktop
- Author data transformation workflows in a simple GUI.

FME Server
- Take FME to the enterprise with enhanced automation.

FME Cloud
- Get the benefits of FME Server in a hosted version.
Coming in FME 2018

- Preliminary GML coverage support
- NetCDF 4.0 support (FME 2017)
- GDAL upgrade
- WCS 2.0 reader
- WCS Server template
- Raster and Coverage examples in the FME INSPIRE Tutorial
FME completes the INSPIRE Life Cycle

- **Evaluation**
  - Data assessment

- **Publication**
  - WxS, GML, PDF, KML

- **Assembly**
  - Formats, Joins

- **Validation**
  - QA, XSD, values

- **Transformation**
  - schema, geometry

- **Write**
  - INSPIRE GML
FME and INSPIRE

FME simplifies the process of achieving EU INSPIRE* compliance - without any coding - through its abilities to:

- **Read INSPIRE** data and services, using a number of readers, including the INSPIRE GML Reader
- **Prepare data** for contribution to INSPIRE through data transformation and schema mapping
- **Write INSPIRE GML** using the INSPIRE GML Writer, with built-in application schemas
- **Validate INSPIRE GML** to ensure compliance with EU standards
- **Share INSPIRE data** using FME Server’s web services
Conclusion

INSPIRE coverage requirements are still evolving and range from simple raster imagery to complex array structures BUT:

- FME gives you access to whatever data is needed
- FME provides full control over your data model
- Share it an way that is easily accessible
- INSPIRE coverages provide opportunities for data integration across modelling environments such as weather and climate models – increasingly important in a climate change context
Resources

**INSPIRE Tutorial:**
[knowledge.safe.com/articles/1321/eu-inspire-initiative-tutorial.html](knowledge.safe.com/articles/1321/eu-inspire-initiative-tutorial.html)

**FME Community:**
[knowledge.safe.com/search.html?f=&q=inspire](knowledge.safe.com/search.html?f=&q=inspire)

**Safe.com:**
[safe.com/inspire](safe.com/inspire)
[hub.safe.com](hub.safe.com)

Search: raster
[playground.fmeserver.com/](playground.fmeserver.com/)

Other tutorials: XML, GML, JSON, 3D

Google: INSPIRE FME
Thank You!

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