Aims of flood mapping and monitoring training course

• Thematic goals:
  – Flood monitoring exploiting EO data
  – Flood analysis

• Synergy assessment between
  – Medium resolution SAR and medium optical image
  – Optical medium and high resolution image
  – Approach of time series
Aims of Flood mapping and monitoring training course

- IP part:
- Image Visualisation and Manipulation
- Flood water extraction
  - Optical and Radar
  - Mono-date and Multidate
- Thresholding
- Change detection
- Flood event characterization

Spectral basis for flood mapping

Applicable to others SAR or optical sensors
Short term goal of flood mapping and monitoring T.C.
Preparing exploitation of the Sentinel series

Sentinel 1
- Resolution same as actual VHR strip map
- Band and Pol same as ENVISAT (C band)
- Large swath
- Revisiting time

(From YI Desnos presentation, Lanzhou, 09-2010)

Sentinel 2
- Resolution same as SPOT5 (10m)
- Presence of a SWIR band
- Large swath (MERIS)
- Revisiting time
Case study - the 2006 Danube flood event

Major floods began in Roumania since the 14 of April 2006 and water stayed in some place for more than 6 months.

Main dike breaks:
- Rast : 14 April 11h30 (local time)
- Bistret - Nedeia, 24 April 2006 à 7h50 LT;
- Bechet - Dabuleni, 24 April 2006, 7h15 LT;
- Dabuleni - Corabia, 27 April 2006, 11:00 LT.

Voluntary break of levees in order to allow the flow escape:
- Nedeia, 3 May 2006
- Orlea - Corabia, 9 May

Input from Corina Alecu & Anisoara Irimescu,
Meteo Roumanie
### EO data covering the 2006 Danube flood event

<table>
<thead>
<tr>
<th>#</th>
<th>Region</th>
<th>Duration</th>
<th>Affected</th>
<th>Damage [million €]</th>
<th>Cause</th>
<th>Annuality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Upper Danube</td>
<td>28.3. - 17.4.</td>
<td>5 dead, 4,000 displaced (mostly in CZ)</td>
<td>~ 110</td>
<td>Snowmelt/deflagration</td>
<td>Lower Morava and Dye about 100 years event</td>
</tr>
<tr>
<td>2</td>
<td>Middle Danube</td>
<td>28.3. - 28.4.</td>
<td>3 dead, 6,000 displaced</td>
<td>~ 30</td>
<td>Snowmelt and rain and locally dike breaks</td>
<td>About 100 years event for the lower reaches of Bodrog and Tisza and the Danube</td>
</tr>
<tr>
<td>3</td>
<td>Middle Danube</td>
<td>4.4. - 28.4.</td>
<td>2 dead, 3,000 displaced</td>
<td>~ 60</td>
<td>Concurrent high discharges of the Danube, Tisza and Sava</td>
<td>At least 100 years event</td>
</tr>
<tr>
<td>4</td>
<td>Lower Danube</td>
<td>7.4. - 15.6.</td>
<td>14,000 displaced</td>
<td>~ 400</td>
<td>Water from middle Danube, Several dike breaks and controlled flooding</td>
<td>About 100 years event</td>
</tr>
</tbody>
</table>

---

### Single event monitoring exploiting HR data

**The Spring 2006 Danube flood case**

![Map showing Romania and Bulgaria](image)
Single event monitoring

17-04-06
Flooding of crop fields
Case study - the 2006 Danube flood event

• Medium resolution optical data: MERIS FR level 1 (300m)
  – 26 March 2006
  – 23 April 2006
  – 22 May 2006

• Medium resolution ASAR data: WSM VV Pol (75 m pixel spacing)
  – 27 March 2006
  – 18 & 24 April 2006

• HR SPOT Image
  – 17, 23 and 6 of April 2006

• HR and VHR optical data: Formosat-2 XS and merged PXS (8 and 2 m)
  – 17 & 25 April 2006

• Reference data
  – SPOT 11 August 2004
  – Landsat 7 ETM Image
  – SRTM DEM

ENVISAT ASAR

• C Band, HH, VV, HV 20° – 49° incidence
• Range of viewing (beam positions)
• 37 different and mutually exclusive operating modes in high, medium (Wide Swath Mode),

Wide swath coverage: 405 km swath with 150 m or 1 km resolution.
• Resolution, 30 m to 1 km
• Data transfer: potential coupling with Artemis
Medium resolution sensor: MERIS

ESA ENVISAT satellite

15 spectral bands,

Programmable in width and position, in the visible and near infrared.

Swath width: 1150 km

Coverage of the Earth in 3 days.

2 resolutions: 1.2 km and 250 m

Full resolution products
- 582 km x 650 km
- 300 km x 334 km
### Medium resolution sensor: MERIS

<table>
<thead>
<tr>
<th>Band</th>
<th>Band centre (nm)</th>
<th>Bandwidth (nm)</th>
<th>Primary Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>412.5</td>
<td>10</td>
<td>Yellow substance and detrital pigments</td>
</tr>
<tr>
<td>2</td>
<td>442.5</td>
<td>10</td>
<td>Chlorophyll absorption maximum</td>
</tr>
<tr>
<td>3</td>
<td>490</td>
<td>10</td>
<td>Chlorophyll and other pigments</td>
</tr>
<tr>
<td>4</td>
<td>510</td>
<td>10</td>
<td>Suspended sediment, red tides</td>
</tr>
<tr>
<td>5</td>
<td>560</td>
<td>10</td>
<td>Chlorophyll absorption minimum</td>
</tr>
<tr>
<td>6</td>
<td>620</td>
<td>10</td>
<td>Suspended sediment</td>
</tr>
<tr>
<td>7</td>
<td>665</td>
<td>10</td>
<td>Chlorophyll absorption and fluo. reference</td>
</tr>
<tr>
<td>8</td>
<td>681.25</td>
<td>7.5</td>
<td>Chlorophyll fluorescence peak</td>
</tr>
<tr>
<td>9</td>
<td>708.75</td>
<td>10</td>
<td>Fluor. Reference, atmospheric corrections</td>
</tr>
<tr>
<td>10</td>
<td>753.75</td>
<td>7.5</td>
<td>Vegetation, cloud</td>
</tr>
<tr>
<td>11</td>
<td>760.625</td>
<td>3.75</td>
<td>Oxygen absorption R-branch</td>
</tr>
<tr>
<td>12</td>
<td>778.75</td>
<td>15</td>
<td>Atmosphere corrections</td>
</tr>
<tr>
<td>13</td>
<td>865</td>
<td>20</td>
<td>Vegetation, water vapour reference</td>
</tr>
<tr>
<td>14</td>
<td>885</td>
<td>10</td>
<td>Atmosphere corrections</td>
</tr>
<tr>
<td>15</td>
<td>900</td>
<td>10</td>
<td>Water vapour, land</td>
</tr>
</tbody>
</table>

---

**THE 2006 DANUBE FLOODS**
Florence Situation Spacemap
The 20th of March 2006

**Legend:**
- Water
- Fields
- Forest
- Urban areas
- Cities

**Map information:**
- Projection: UTM Zone 35 North
- Scale: 1:250,000

**Data sources:** ERB/SAT MERIS data
Acquired the 20th of March 2006
© ESA 1999

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* 6th Advanced Training Course in Land Remote Sensing
  1–5 July, 2011 | Harokopio University | Athens, Greece
### SPOT constellation

<table>
<thead>
<tr>
<th>Capteurs</th>
<th>Spectre électromagnétique</th>
<th>Taille des pixels</th>
<th>Bandes spectrales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot 5</td>
<td>Panchromatique</td>
<td>2,5 m ou 5 m</td>
<td>0,48 - 0,71 μm</td>
</tr>
<tr>
<td></td>
<td>B1 : vert</td>
<td>15 m</td>
<td>0,49 - 0,89 μm</td>
</tr>
<tr>
<td></td>
<td>B2 : rouge</td>
<td>10 m</td>
<td>0,61 - 0,68 μm</td>
</tr>
<tr>
<td></td>
<td>B3 : proche</td>
<td>20 m</td>
<td>0,79 - 0,99 μm</td>
</tr>
<tr>
<td></td>
<td>infrarouge</td>
<td></td>
<td>1,56 - 1,75 μm</td>
</tr>
<tr>
<td></td>
<td>infrarouge (MIR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spot 4</td>
<td>Monospectral</td>
<td>10 m</td>
<td>0,61 - 0,68 μm</td>
</tr>
<tr>
<td></td>
<td>B1 : vert</td>
<td>20 m</td>
<td>0,50 - 0,59 μm</td>
</tr>
<tr>
<td></td>
<td>B2 : rouge</td>
<td>20 m</td>
<td>0,61 - 0,68 μm</td>
</tr>
<tr>
<td></td>
<td>B3 : proche</td>
<td>20 m</td>
<td>0,79 - 0,89 μm</td>
</tr>
<tr>
<td></td>
<td>infrarouge</td>
<td>20 m</td>
<td>1,56 - 1,75 μm</td>
</tr>
<tr>
<td></td>
<td>infrarouge (MIR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spot 1</td>
<td>Panchromatique</td>
<td>10 m</td>
<td>0,50 - 0,73 μm</td>
</tr>
<tr>
<td>Spot 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spot 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Continuity of the SPOT service: functioning in conjunction with SPOT 2, SPOT 4
- Improvement of the spatial resolution
- Improvement of the accuracy
- Launched 4 of May 2002
- Data available since end of Spring 2002
Mid term goal of flood mapping and monitoring T.C.
Preparing the Sentinel series

Sentinel 2
• Resolution same as SPOT5 (10m in Vis PIR)
• Presence of a SWIR bands
SPOT 11 – 08 – 2004

SPOT 5 Products

SPOT 17 04 2006

4th ADVANCED TRAINING COURSE IN LAND REMOTE SENSING
1–5 July 2011 | Harokopio University | Athens, Greece
Formosat-2 satellite

- FORMOSAT-2 – a particular orbit
  - 891 km: sun-synchronous & geo-synchronous
  - Exactly 14 orbits/day
  - Daily revisit of accessible areas,
  - with the same incidence angle
  - GSD & swath pre-determined
  - 9:30 am Local Time at descending node

Formosat satellite

- FORMOSAT-2 imaging capabilities
  - 2-m pan / 8-m colour
  - Swath width @ NADIR: 24 km
  - 4 spectral bands (B,G,R,PIR – delivered R,G,B,PIR)
  - On board memory: 40 Gbit
  - High agility: stereo along the track and fast roll access
  - 8 minutes imaging per orbit – can’t cover the full orbit
Formosat-2 multispectral data

17-04-2006
8 m

Formosat-2 multispectral data

25-04-2006
8 m
Image analysis

**First step: Taking image in hands**

- Work on band combination (Meris)
- Work on lut (breakpoints)
- Zoom in /out
- Superpose images

=> **Very important step, manipulate image gives the opportunity to learn the images in terms on landscape units**
MERIS FR Data

- Try different band combinations
- Compare the dates (overlay/swipe/geo-link/blend)
  - Have a look at the different landuse classes
    - Urban
    - Water, different turbidity (lakes, rivers)
    - Grasslands
    - Forestry
    - Bare soil
    - Cropland

What do you think of them?
- Can you find composites to highlight landuse themes?
- Natural colours
  - 8-5-4 in RGB
  - Swap channel 4 with channel 1 → more atmospheric effects
  - Analyse water colours in terms of turbidity (speed) / depth
- False colour composites
  - 14-9-3 in RVB
  - 12-8-3 in RVB
  - 8-12-2 in RVB
**ASAR WSM Data**

- **Gamma filtered images**
  - Apply it only to the ASAR image acquired the 24-04-06

- Compare with ASAR WSM unfiltered data and filtered data (overlay/swipe/geo-link/blend)
  - Have a look on the different landuse classes:
    - Urban
    - Water, variations of backscattering (wind effect)
    - Grasslands
    - Forestry
    - Bare soil
    - Cropland

**SPOT Data**

- Try band combinations (321, 432, 342)

- Compare Channel 1 versus 2, 2 versus 3, 3 versus 4

- Compare the different dates (overlay/swipe/geo-link/blend)

- Have a look on the different landuse classes
  - Urban structures
  - Water
  - Grasslands
  - Forestry
  - Bare soil
  - Cropland

- Analyse water colours in terms of turbidity (speed) / depth
Formosat-2 Data

- Try band combinations
- Compare the two dates (overlay/swipe/geo-link/blend)
  - Have a look on the different landuse classes
    - Urban and harbour structures (warehouse and cranes)
    - Water, different turbidity
    - Grasslands
    - Forestry
    - Bare soil
    - Cropland

Flood products

- Water extent at each date
- Dynamic of flooding
- Damage assessment (Formosat PXS)
**Water extraction**

- ENVISAT MERIS FR
  - Single band
  - Double threshold: NDVI mean + Band 15 (PIR)

- ENVISAT ASAR WSM
  - Threshold

- SPOT
  - Single band (PIR = channel 1)
  - Classification approach
  - Double threshold: indices (HIS transform) and channels for more advanced trainees
  - Change detection for the more advanced

- For each: validation by PIAO (visualization and screen digitalization)

---

**Water extraction**

*Flood mapping based on thresholding of raw channel*

**Fundamentals: Spectral signature of water**

NIR and SWIR are absorbed
Water extraction

Water extraction based on monotemporal approach (thresholding)

Neighbourhood influence on threshold definition

SPOT XS3
Threshold = 50

SPOT XS3
Threshold = 75

Extraction of water: urban neighbourhood
Water extraction

Flood mapping based on thresholding of indice

Fundamentals: water areas can be very bright if containing suspended materials

Extraction of water bodies from:

- Brightness Standard or Tasseled Cap
- First component of a PCA,
- Saturation indices of a HIS transformation

Water extraction

When flooded area extraction is carried on single channel/indice such as brightness, saturation, there is some possible confusion between very bright water areas and some very chlorophyll zones

Combination of normalized vegetation and of brightness or saturation indices allow to extract only flooded area
Water extraction

Flood mapping based on optical data: combination of indices

- Channel XS1
- Channel XS2
- Channel XS3

NDVI computation

Histogram computation

Threshold definition

Differentiation vegetal/none vegetal

Combination

Differentiation bright/dark areas

Water extraction

Flood mapping based on classification

Classification can be performed on:
- Raw flooded data
- Combination of indices

Methods of classification
- Supervised
- None supervised
- Oriented object methods
- SVM

Flooded data

Selection of water aoi + others themes

AOI signatures edition

Classes' statistics computation

Supervised classification

Classified image

Selection of water classes

WATER
Your work on the Danube data set

• **Meris FR**
  - Double Threshold: NDVI and C15
  - Two steps: first compute the NDVI
  - Threshold step

• **SPOT images**
  - Single band (NIR on SPOT 3, SWIR on SPOT 4)
  - Classification approach via quick alarm
  - Double threshold:
    - indices (HIS transform) and channels
  - Change detection
    - Reference/crisis
    - Crisis/crisis

Water extraction

**calculation of NDVI\textsubscript{mean}**

\[
NDVI\textsubscript{mean} = \frac{1}{n_{\text{pir}}} \sum_{i=10}^{15} DN - \frac{1}{n_{\text{red}}} \sum_{i=6}^{9} DN
\]

\[
\frac{1}{n_{\text{pir}}} \sum_{i=10}^{15} DN + \frac{1}{n_{\text{red}}} \sum_{i=6}^{9} DN
\]

\( i = \) band number
\( DN = \) reflectance value
\( n_{\text{pir}} = \) number of near infrared bands
\( n_{\text{red}} = \) number of red bands
Water extraction

MERIS - double threshold

<table>
<thead>
<tr>
<th>Data</th>
<th>Band 15</th>
<th>NDVI&lt;sub&gt;mean&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006/03/26</td>
<td>19</td>
<td>-0.250</td>
</tr>
<tr>
<td>2006/04/23</td>
<td>22</td>
<td>-0.025</td>
</tr>
<tr>
<td>2006/05/22</td>
<td>22</td>
<td>0.100</td>
</tr>
</tbody>
</table>

Apply it to the MERIS image acquired the 23-04-06

Water extraction

MERIS - correction and validation

- Compare the thresholded water extraction image with the original image
- Exploiting the recode tool
  - correct and validate the water extent layer
Water extraction

**ASAR WSM Data**

- Simple approach: single threshold

<table>
<thead>
<tr>
<th>Data</th>
<th>Threshold value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006/03/27</td>
<td>101000000</td>
</tr>
<tr>
<td>2006/04/18</td>
<td>101300000</td>
</tr>
<tr>
<td>2006/04/24</td>
<td>101000000</td>
</tr>
</tbody>
</table>

Apply it to the ASAR filtered image acquired the 24-04-06

---

**Water extraction**

**SPOT** : simple threshold

Analyse exploiting the cursor values of water in band 3 or 4 (NIR or SWIR)

Indicative threshold values:
- 17 April : 26-30 DN (band 4)
- 23 April : 50 (band 3)
- 26 April : ca 45 (see flooded forest)
Water extraction on SPOT : simple threshold

17 April : 3-4-2 in RGB

Water extraction on SPOT : simple threshold

17 April : channel SWIR : 4
Water extraction on SPOT: simple threshold

Indicative threshold values:

17 April: 30 DN

SPOT: water extraction via classification
SPOT: water extraction via classification
SPOT: water extraction via classification

Clouds also integrated: need to correction

SPOT1: water extraction via classification

Exploitation of AOI tools and recode (from raster on the viewer)
Water extraction

SPOT : change detection

Can be applied to:

Reference versus crisis data

Different data from crisis set

As optional work
Can also be applied to the formosat crisis pair of images
SPOT: change detection: reference/crisis

SPOT 4: 2002-04-17 crisis image

SPOT 4: 2002-04-17 channel 4 SWIR
Access to the Change detection module

SPOT 11-08-2004   SPOT 17 - 04 -06

Work on channel 4 (SWIR)
Value 2 & 10 %

SPOT : change detection: reference/crisis

Change channel
Two values: decrease/increase
Access to the Change detection module

Put value 1 and 20 %
SPOT : change detection: crisis/crisis

SPOT 4 : 2002-04-26 crisis image

SPOT : change detection: crisis/crisis

SPOT 4 : crisis diff_change
SPOT : change detection: crisis/crisis

Correction exploiting the recode tool
SPOT: change detection: crisis/crisis

Cyan: new water from 17 to 26 of April 2006

ASAR: correction and validation

- Compare thresholded water mask with:
  - original images
  - the closest MERIS image in time (in order to avoid confusion/mis-classification in crop fields)

- Exploiting recode tool
  - correct and validate the water extent layer
Flood products

- Water extent at each date
- Dynamic of flooding
- Damage assessment (Formosat PXS)

Water layer comparison

- Medium resolution water layer comparison
  - MERIS 26-03-2006 and WSM 27-03-2006
  - MERIS 23-04-2006 and WSM 24-04-2006

- Compare Medium resolution water layers and HR/VHR Formosat images or SPOT image data
  - WSM 18-04-2006 and Formosat 17-04-2006
  - MERIS 23-04-2006 and Formosat 25-04-2006
  - WSM 24-04-2006 and Formosat 25-04-2006

- Compare Formosat and SPOT images
  - WSM 18-04-2006 and Formosat 17-04-2006
  - MERIS 23-04-2006 and Formosat 25-04-2006
  - WSM 24-04-2006 and Formosat 25-04-2006

→ Conclusion
  - Are they coherent, complementary
Flood products

THE 2004 DANUBE FLOODS
Situation the 26th of March 2004

Legend:
- Settlements
- Reference water
- Flood extent the 2004/02/26
- Low-lying vegetation
- Woody vegetation

Map information:

Data sources:
ENVIROSAT MERIS data of the JRC/ESA 2004
© Esa 2004
Topography & reference water: SRTM 30m
© USGS 2000
Land cover: ECDIT database Processing ECDIT 2004
© ECDIT 2000

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4th ADVANCED TRAINING COURSE IN LAND REMOTE SENSING 1-5 July 2003 | Harokopio University | Athens, Greece
Flood Analysis

• From flood dynamics...

... to flood damage
Flood mechanisms in relation to flood plain morphology
Flooding of the lowlands bordering the Danube River

Floods invade two major zones – getting in behind dikes and levées

Dike break
Dikes & Levées

Map Information:

Data sources:

- ENVISAT ASAR VV data of the 20/08/2003 (V1) and ENVISAT ASAR VV data of the 20/09/2003 (V1)
- Land cover: DERTIT database Processing DERTIT 2007
- Topography & reference water: SRTM 2000
- © UOSGS 2000

Map Information:

Data sources:

- ENVISAT ASAR VV data of the 20/08/2003 (V1) and ENVISAT ASAR VV data of the 20/09/2003 (V1)
- Land cover: DERTIT database Processing DERTIT 2007
- Topography & reference water: SRTM 2000
- © UOSGS 2000
Downstream flood flow retarded by dykes and levées: 

Flooding of Rast & Lom

Downstream floods flow

Dike breaks
After the flood peak of April, floods move downstream

**Flood Analysis:**
examples of event summarising hydro-dynamical products

- **Compute:**
  1. Maximum Flood extent
  2. Estimated Flood duration

- **Compare:**
  - Estimated flood duration with
  - the flood progression layer (given)
Flood analysis: maximal extent = Alea

Compute

- Flood maximal extent (see model)
Flood analysis: Duration

Compute

- Estimated flood duration (see model)
Optional work
Compute dynamic by pair of dates

Optional work
Exploit obtained dynamic computed for pair of dates
Lakes - Floods monitoring practical

Dr Yésou H.

With contributions of SERTIT Rapid Mapping team

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4th of July 2013, D4P1a