Abstract – During the August 2002 Elbe river flood, different satellite data were acquired, and especially ASAR data from ENVISAT. The Advanced Synthetic Aperture Radar instrument was activated in different image modes. Thus, the comparison with quasi-simultaneous ERS-2 data enables to evaluate the contribution of polarisation configurations on flood surface detection. This study highlights the increased capabilities of ASAR for flood mapping, especially benefit of a common use of like- and cross-polarisations.

Index Terms – ENVISAT ASAR; Flood mapping; Alternating polarisation.

I. INTRODUCTION

With ten instruments, ENVISAT enables scientists to study many parts of environmental processes [1]. The technologies of ENVISAT have been inspired by precursor Earth observation satellites missions [2]. The use of synthetic aperture radar, with many different imaging modes, is well suited for flood risk management and land cover descriptions. The main purpose of this paper is focussed on the Advanced Synthetic Aperture Radar (ASAR), especially its high resolution imaging modes, with different single and alternating polarisations. The ASAR is able to acquire data with alternating polarisation (AP). The corresponding product is then furnished as two images acquired with three possible polarisation combinations: HH and VV, HH and HV, VV and VH. In single polarisation mode (IM), ASAR improves the heritage of ERS missions by offering two polarisations (HH and VV), variable incidence angles and better radiometric resolution. General specifications of ASAR system and data products are presented by ref. [3] and [4].

Multi-polarisation has many interests and especially that of crop monitoring [5] or land use mapping [6]. For the latter, [7] proposes a synthetic overview of the use of multi-frequency, multi-polarisation and multi-incidence synthetic aperture radar.

Ref. [8] presents a flood extent mapping methodology using QuickSCAT data, which operates in Ku-Band (13.4 GHz) with two polarisations, HH and VV. Based on the polarisation inversion of the electromagnetic wave when reflecting on water surfaces, it uses the \( \sigma_{vv}/\sigma_{hh} \) ratio and the incidence angle difference between the two data. This appears to be more efficient than the analysis of the backscattering coefficient \( \sigma_0 \). Thus, for a flooded area, and the ratio is then less than 1, when plotted on a linear scale. These results are confirmed by the thematic study performed by ref. [9], using a multi-temporal polarimetric dataset on different land use classes. This study clearly shows the potentialities of horizontal like-polarised datasets to isolate open water areas.

II. THE AUGUST 2002 ELBE RIVER FLOOD

During August 2002, very important rainfall occurred on central European alpine basins resulting in the most important flood of the Elbe River and its tributaries. This flood was even more severe than the 1845 flood: during that event, the Elbe River reached a 8.77 m height in Dresden. During the 2002 event in Dresden, the river height was about 9.50 m. The flood wave started in the Czech Republic, severely affecting the majority of the territory, and especially the city of Prague. Then the flood flowed northwards, to Germany.

This event was quite slow: the flood wave entered Germany, in the Sachsen Land, on the 17th of August and the flood maximum reached the city of Hohnstorf five days later. Because of this low propagation speed, EO satellites have acquired useful data, enabling their synergistic use and study.

III. DATABASE CONSTITUTION

During the Elbe flood event of mid-August 2002 in Germany, ENVISAT acquired ASAR data using several imaging modes. Additionally, ERS data were acquired quasi simultaneously. For data analyses, ERS SAR archives and optical data from SPOT and Landsat systems were made available. The first step was to build up a database over the Elbe basin, downstream Dresden city. Geometric correction were applied on the Envisat, ERS and optical data in order to obtain a homogenous database in the same map projection (Gauss-Krüger for Germany) and to integrate the dataset into a GIS allowing the analysis and comparison of the different imaging modes.
IV. POTENTIAL OF POLARISATION

The AP SAR data were acquired with HV and HH polarisation combinations. Their thematic contents and their mutual improvements are analysed, compared to ERS SAR data. Their study can be performed furthermore with ERS and Landsat data, to evaluate how useful multi-polarisation can be for land description and flood extent delineation.

A. Land cover description

The polarisation configuration of the SAR instrument has an impact on surface description. Photo interpretation of the three polarisations combination enables the consideration of the specific capabilities of each of them for detecting different land use themes (Table I).

<table>
<thead>
<tr>
<th></th>
<th>HH</th>
<th>HV</th>
<th>VV</th>
</tr>
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<tbody>
<tr>
<td>Forest</td>
<td>+</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Fields</td>
<td>++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Urban areas</td>
<td>+++</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>Flooded areas</td>
<td>+++</td>
<td>++</td>
<td>+</td>
</tr>
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Moreover, colour composition of these polarised datasets shows more clearly the contribution and complementarity of each acquisition mode (Fig. 1a). It stresses the ability of HV polarisation to identify forested areas and distinguish them from bare soils fields. Obviously, many benefits can be retrieved by the combined use of HH and HV polarised datasets.

B. Flooded area detection

Because of the specular effect of the radar signal on water surfaces, this type of surface appears generally dark corresponding to a low signal return. However, when the water surface is not totally flat but disturbed by wind conditions or streams, the rough water surface could appear in different grey levels and it is therefore difficult to dissociate it from the other type of land cover. Depending on the different polarisation and imaging modes of ASAR, the water surfaces can be more or less identified. The analysis of the backscattering behaviour on water surfaces, depending on the polarisation configuration, is performed in order to identify the most suitable polarisation for its identification. As for land description, this analysis is performed by using Envisat ASA-APP HH and HV polarisations, with ERS-2 VV polarisation data, both acquired on the 08/19/02, within half an hour.

The first analysis of the general statistics of the three images clearly shows secondary picks in the lowest DN values of HH and VV datasets (Fig. 2). This imply that open water and flooded areas would be easier to identify with like-polarised data rather than cross-polarised. It was also noticed that HH data histogram is wider than the others (i.e. higher radiometric dynamics), implying a better differentiation of thematic classes.

Figure 1. Colour composition of HH, HV and VV in RGB (a), and spectral profile across a river transect (b)

Figure 2. Histograms HH, HV and VV polarised data
Using a thresholding technique, flood extent was derived from APP-HH, HV and ERS VV polarised SAR data. Following these results, the use of HH polarisation seems to be more efficient to distinguish flooded areas. Despite this, there is a difference in the flooded area discrimination according to the polarisations. It is observed that some areas are only detected by one polarisation configuration (Table II). For this point, HV provides an important contribution, even the total detected surface is fairly equivalent. Table II illustrates the benefits that can be retrieved from the use of different polarisations for flood mapping.

<table>
<thead>
<tr>
<th>Polarisation (Threshold)</th>
<th>Numbers of pixels detected</th>
<th>Superficies (ha)</th>
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<tbody>
<tr>
<td>HH (300)</td>
<td>264355</td>
<td>4130.5</td>
</tr>
<tr>
<td>HV (150)</td>
<td>262810</td>
<td>4106.4</td>
</tr>
<tr>
<td>VV (200)</td>
<td>211612</td>
<td>3306.4</td>
</tr>
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</table>

Radiometric profiles over river transects clearly shows that HH polarised signal is less backscattered by open water than HV or VV (Fig. 1b). This tends to confirm observations formulated by ref. [7]. In addition, the better radiometric dynamic of HH polarisation is clearly illustrated as far as the better separation of water surfaces from the other types of land cover. Similar observations are made on IMP dataset. As with APP HH data, flooded areas are better identified on IMP HH than with ERS-2. In addition IMP gives a better landscape description with more contrast on agricultural fields, urban areas or forests. This is also due to the better radiometric resolution of IMP products (ENL=3.69 according to ref. [11]). Therefore, taking into account only one polarisation, IMP with HH polarisation seems to be more suitable for flood mapping and mostly better than ERS-2 data. However, the use of AP datasets takes advantage of the complementarities of each polarisation, even if the radiometric resolution is slightly affected.

### V. CONCLUSIONS

For this study, we were interested in IM and AP precision image using different polarisations. It shows that in this case study the Image Mode in HH polarisation with its high radiometric dynamic and reduced sensitivity to water surface roughness due to wind provides very useful information. Cross-polarisation seems to be better in the identification of the landscape’s characteristics and an interesting contributor for flood extent mapping but Alternating Polarisation mode features a slightly lower radiometric resolution. Finally, VV polarisation in IM or AP seems to provide less information for the application of flood monitoring.

In addition of multi-polarisation, with it’s steering capabilities or the different spatial resolutions, the Envisat satellite offers an increased revisit frequency. This is an additional advantage offered by Envisat, which constitutes the centre of an EO-based service currently developed by SERTIT, within the framework of Earth Observation Market Development of the European Space Agency [12]. Improving the production chain of EO derived mapping products to take into account the whole capacities of Envisat’s instruments is the one of the key factor to offer a fully operational support for flood management.

### ACKNOWLEDGEMENTS

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### REFERENCES