GlobVolcano Project Overview

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***Abstract*— The GlobVolcano project is part of the ESA DUE programme. The project aims at demonstrating EO-based services to support the Volcanological Observatories and other mandate users (e.g. Civil Protection authorities, scientific communities of volcanoes) in their monitoring activities.**

During the project a worldwide selection of user organizations will cooperate with the GlobVolcano team in order to harmonize user's requirements and to evaluate the EO-based services . The "Osservatorio Vesuviano" of Naples (INGV-Italy) coordinates the communications between the project and the User Community. IPGP of Paris is responsible for the scientific coordination and the validation activities.

The project activities are split in two phases. During the first phase (completed in June 2008) the service infrastructure and interface to the users have been developed. Prototype EO-based information products have been generated and validated. Service provision on pre-operational basis will take place during the second phase.

Keywords-component; Volcano, Earth Observation, Information Service

I. INTRODUCTION

The objective of the GlobVolcano project is to define, implement and validate an EO (Earth Observation) based information system able to support the activities of volcanic observatories, civil protection agencies and the broader scientific community of volcanoes with validated EO products.

The four EO based information services, each one related to the different responsibility areas of the institutions engaged in volcano surveillance, are:

- Deformation Mapping (DM)
- Surface Thermal Anomalies (STA)
- Volcanic Gas Emission (SO_2)
- Volcanic Ash Tracking (ASH)

The GlobVolcano Information System consists of two main elements:

- The GlobVolcano Data Processing System includes the set of EO data processing subsystems. The processing subsystems are located at each respective service center.
- The GlobVolcano Information Service is the provision infrastructure, i.e. the interface to the end users.

The GlobVolcano Information System was defined following a modular approach in order to identify for each user organization one or more information services suitable for its volcano(es) of interest.

During the first phase of the project, the information system architecture was developed and assessed in close cooperation with the user organizations. The second phase of the project will concern service provision and products delivery. User Organizations will integrate GlobVolcano products in their working environment and provide GlobVolcano team with an evaluation about the usefulness of the EO products in their daily practice.

II. GLOBVOLCANO DATA PROCESSING SYSTEM

The GlobVolcano Data Processing System is devoted to EO data processing and GlobVolcano products generation. It consists of seven data processing sub-systems based on existing and mature processing techniques.

A. Deformation Mapping Service

The Deformation Mapping Service is useful in order to analyze and understand the geophysical mechanisms governing the volcanic system and its dynamic characteristics. Two different processing approaches are adopted in order to provide both global and detailed monitoring of the area of interest: Conventional DInSAR (Differential Synthetic Aperture Radar Interferometry) and PSInSAR™ (Permanent Scatterers Synthetic Aperture Radar Interferometry). Both processing approaches exploit Envisat ASAR data in order to generate GlobVolcano products.

The use of Conventional DInSAR approach allows increasing temporal resolution of deformation mapping products when the alert level increase by exploiting capability of ASAR sensor to image an area with different geometry.

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Furthermore, DInSAR analysis is advantageous for the detection of fast deformation, since it can supply users with interferograms providing useful information at least for a first qualitative analysis.

On the other hand, PSInSAR™ exploits a point-wise approach and provides high accurate deformation estimation (Atmospheric Phase Screen estimation and removal) for a set radar targets exhibiting a coherence level constant in time, called Permanent Scatterers.

1) Conventional DInSAR provides accurate deformation estimates of wide areas. This service is useful when an high temporal resolution is required (e.g. in case of alert level escalation). The software tool EarthView® InSAR (MDA Inc.) is adopted in order to implement this service. The convetional DInSAR Service is located at MDA Inc. (Canada).

2) PSInSAR™ allows the monitoring of the temporal evolution of the deformation over long time period. The mesurements points identified over the area of interest can be considered a sort of "natural geodetic network". The deformation of each point is measured with a millimetre accuracy. PSInSAR™ Service is located at T.R.E. (Italy).

B. Surface Thermal Anomalies Service

The Surface thermal Anomalies Service is based on the synergetic use of:

- High spatial resolution satellite data acquired over long revisit intervals by ASTER (onboard TERRA), and HRVIR or HRGT (onboard SPOT-4 and -5).
- Low spatial resolution satellite data acquired with daily frequency by MODIS (onboard TERRA and AQUA).

The combined use of the above instruments allows to increase the frequency of observation and the level of detail. Suitable EO data and processing methodology depend also on heat intensity and the size of the thermal volcanic anomaly.

- TERRA ASTER data allows dealing with both high (i.e. summit crater activity, active lava flows, lava lakes, lava fountains, lava domes) and low temperature (i.e. pyroclastic flows and lava flow cooling, crater lakes, low-temperature fumarolic fields) surface anomalies.
- SPOT-4/5 (HRVIR / HRGT) data allows dealing with low temperature surface anomalies (i.e. active lava flows and lava lakes).
- TERRA/AQUA MODIS data allows dealing with high temperature surface anomalies (i.e. summit crater activity, active lava flows, lava lake, lava fountains, lava dome).

Therefore, the choice of the EO-data and the processing methodology is a function of the eruptive style, the volcano dynamics and the expected/observed thermal anomaly associated.

Two software tools are adopted for the implementation of the service:

- MyVOL (IESConsulting): high spatial resolution surface thermal anomalies.
- MyMOD (IESConsulting): low-spatial resolution/high-temporal resolution surface thermal anomalies.

The Surface Thermal Anomalies Service is located at CGS. (Italy).

C. Volcanic Gas Emission (SO_2) Service

The Volcanic Gas Emission (SO_2) Service is provided to the users by a link to GSE-PROMOTE – Support to Aviation Control Service (SACS). The aim of the service is to deliver in near-real-time data derived from satellite measurements regarding SO_2 emissions possibly related to volcanic eruptions. Global observations of SO_2 derived from satellite measurements in near-real-time may provide useful complementary information to assess possible impacts of volcanic eruptions on public safety. Furthermore, the monitoring of SO_2 volcanic emission is useful in the frame of early warning, as eruption precursor.

The service is focused on the timely delivery of SO2 data derived from different satellite instruments, such as SCIAMACHY, OMI and GOME-2. The exploitation of these instruments allows the generation of three different kinds of products:

- SO2 Notification: exceptional SO2 concentration is automatically notified via e-mail to subscribed users.
- Near Real Time: SO2 vertical column density (Dobson Unit - DU) available within 3-6 hours after measurements.
- Archive: global maps are usually available about 2 weeks after the end of the months and generated by reprocessing monthly acquisitions.

The Volcanic Gas Emission (SO_2) is located at: BIRA IASB Belgium (SCIAMACHY data), KNMI The Netherlands (OMI data) and DLR IMF German (GOME 2 data).

D. Volcanic Ash Tracking Service

The Volcanic Ash Tracking Service is provided to the users by a link to GSE-PROMOTE – Support to Aviation Control Service (SACS). The aim of the service is to track the ash injected into the atmosphere during a volcanic eruption. The tracking of volcanic ash is accomplished by using a proper RGB composite with BTD (Brightness Temperature Differences) relative to SEVIRI-MSG Infrared channels: 8.7 μm (IR8.7), 10.8 μm (IR10.8) and 12.0 μm (IR12.0). Table I describes the components used for the RGB composite. This service takes advantage of the MSG SEVIRI Scan cycle (15 minutes). Thus the provided product is an animated temporal sequence (i.e. animated GIF). The temporal resolution of the sequence is, at best, 15 minutes. The Volcanic Ash Tracking Service is located at CGS. (Italy).

III. GLOBVOLCANO INFORMATION SERVICE AND USER INTERFACE

The GlobVolcano Information Service is the product provision infrastructure of the GlobVolcano Information System and includes the following elements:

- GlobVolcano Products Archives,
- GlobVolcano Metadata Catalogue and
- GlobVolcano User Interface (GVUI).

GlobVolcano Products Archives store GlobVolcano products generated over the areas of interest during the project. Each GlobVolcano products archive offers two main functionalities: WMS (Web Map Service) for products visualization through the GVUI and products delivery / downloading.

The GlobVolcano Metadata Catalogue stores metadata related to each GlobVolcano product available in the product archives and to dataset available for the areas of interest (volcanoes) analyzed during the project. The GlobVolcano Metadata Catalogue offers CS-W (Catalogue Service for Web) functionality to store and query metadata of geographic datasets in a catalogue.

The GlobVolcano User Interface is the front end for the user and it uses the Virtual Earth platform as its base. Microsoft Virtual Earth is a map viewer application running in any browser. The GVUI uses AJAX (Asynchronous JavaScript and XML) to implement the interface with GlobVolcano users, and server side VB.net programs to query and access GlobVolcano metadata and products.

The GVUI offers the following functionalities:

- Geographic area selection and visualization
- Metadata search and visualization
- User Login
- Products search
- Products selection and visualization
- Products selection and delivery (download)

Two different access points are distinguished in the GVUI:

- Private User Interface for registered users, and
- Public user Interface for not registered users.

All the above functionalities are available for registered users, whereas only a subset of functionalities is available for not registered users (i.e. geographic area selection and visualization, Metadata search and visualization).

Besides these functionalities, the GVUI offers the basic Virtual Erath functionalities, such as zooming, panning, base layer selection (satellite aerial image, road map or both), 2D and 3D view, oblique aerial view (bird's eye view is available only for limited location, mostly urban).

Fig. 1 shows an example of products visualization exploiting the GlobVolcano User Interface and the 3D view. The pictures reports a deformation mapping product generated over Piton the la Fournaise (La Reunion).

By exploiting the GVUI each GlobVolcano user is able to: explore the GlobVolcano metadata catalogue, identify GlobVolcano products available over his volcano(es) of interest, visualize metadata, visualize GlobVolcano products, and download GlobVolcano products.

IV. PHASE 1 ACTIVITIES RESULTS

The first phase of the project concerned:

- harmonization and consolidation of the users' requirement;
- definition and development of the GlobVolcano Information System;
- generation of the prototype products; and
- validation of surface thermal anomalies and deformation mapping products.

The User Organizations and Volcanoes involved in phase 1 activities are graphically represented in Fig. 2. The picture shows the geographic distribution of the volcano sites.

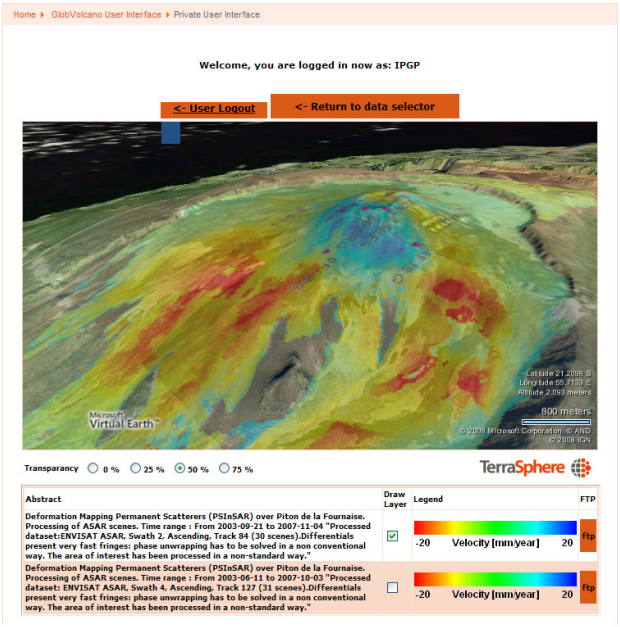

Figure 1. GVUI - Example of deformation mapping product visualisation exploiting the 3D view. Area of interest:Piton de la Fournaise, La Reunion.

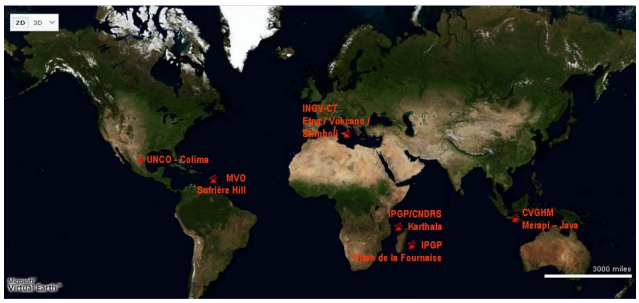

Figure 2. Geographic distribution of User Organisations and volcanoes invoved during phase 1 actvities.

Table II summarizes the service cases carried out during the prototype products generation.

The validation activities concerned:

- Surface thermal anomalies products generated for Piton de la Fournaise (La Reunion) and Karthala (Comoros).
- Deformation Mapping products generated for Piton de la Fournaise (La Reunion).

Form Fig. 3 to Fig. 12: examples of prototype products.

TABLE I. TEST SITES SELECTED FOR THE PROTOTYPE PRODUCTS GENERATION AND RELATED SERVICES.

User	Test site	DM	STA	SO_2
MVO	Soufrière Hills / Montserrat		MyVOL MyMOD	X
INGV-CT	Etna / Sicily		MyMOD	X
	Vulcano / Eolie	PSInSAR™	MyVOL	X
	Stromboli / Eolie	PSInSAR™		X
IPGP	Piton de la Fournaise / La Reunion	PSInSAR™	MyVOL MyMOD	X
CNDRS	Karthala / Comoros		MyVOL MyMOD	X
University of Colima		DInSAR		X
CVGHM	Merapi / Java	DInSAR		X

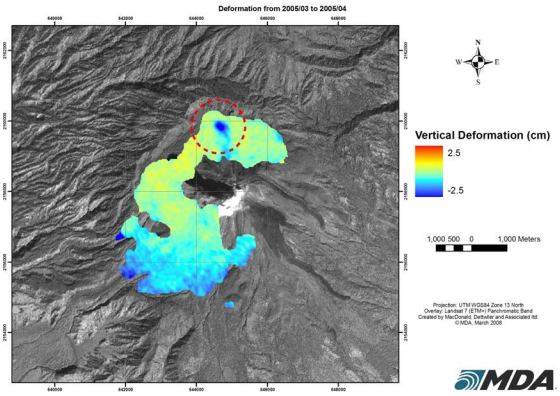

Figure 3. Colima (Mexico) - Example of DInSAR deformation map (Envisat ASAR Interferometric pair: 2005-03-04 – 2005-04-08). The red circle shows a location of interest where deformation is detected.

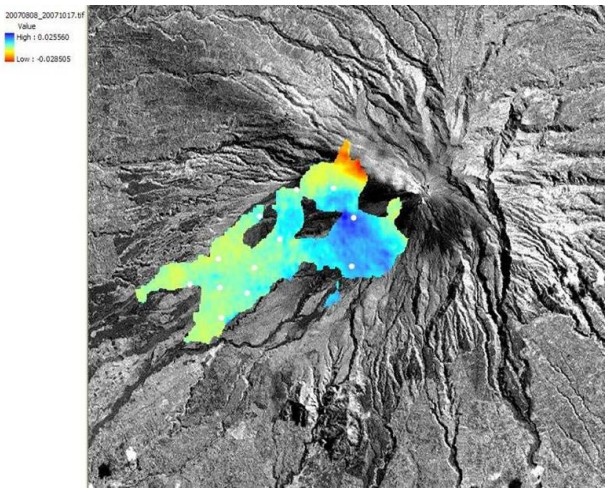

Figure 4. Merapi (Java) - Example of DInSAR deformation map (Envisat ASAR Interferometric pair: 2007-08-08 – 2007-10-17).

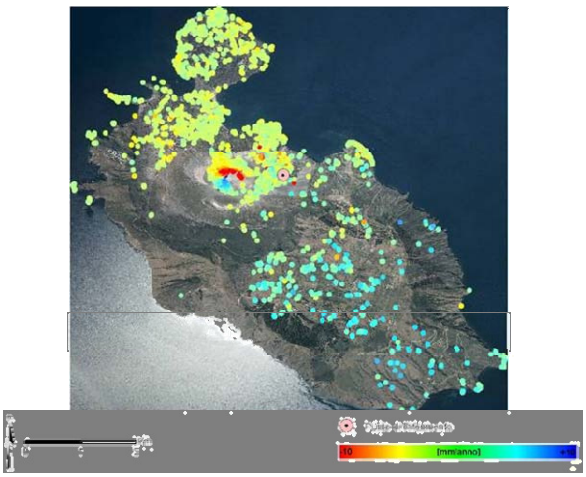

Figure 5. Vulcano (Eolie) - Example of PSInSAR™ Velocity field along LOS. Envisat ASAR ascending dataset. Time range of investigation: 2003-01-11 –2007-11-07.

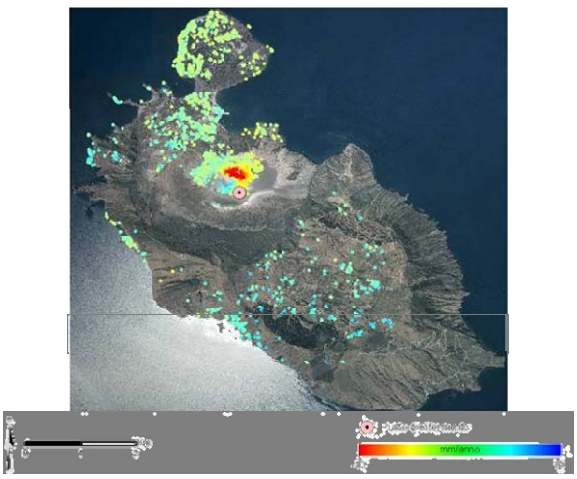

Figure 6. Vulcano (Eolie) – Example of PSInSAR™ Velocity field along LOS. Envisat ASAR descending dataset. Time range of investigation: 2003-07-07 – 2007-10-10.

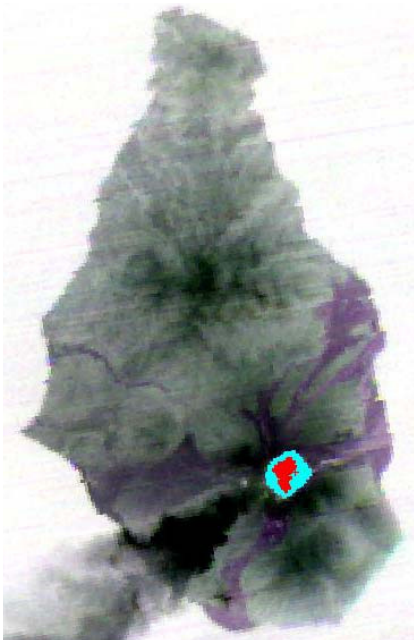

Figure 7. Soufrière Hills (Montserrat) - High spatial resolution surface thermal anomalies product obtained by processing TERRA-ASTER data (2006-02-19). Red points identify high temperature anomalies, blue points identify low temperature anamalies (Lava dome).

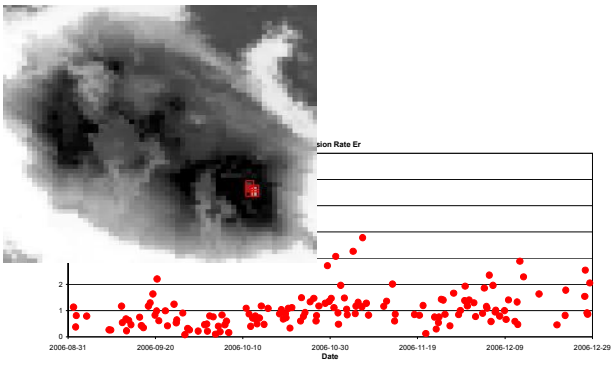

Figure 8. Piton de la Fournaise (La Reunion) – Low spatial / high temporal resolution surface thermal anomalies product obtained by processing MODIS data. Layer of point selected as hot spot (high temperature anomalies), and temporal sequence of Radiant Effusion Rate E_r (from 2006-09-01 to 2006-12-29)

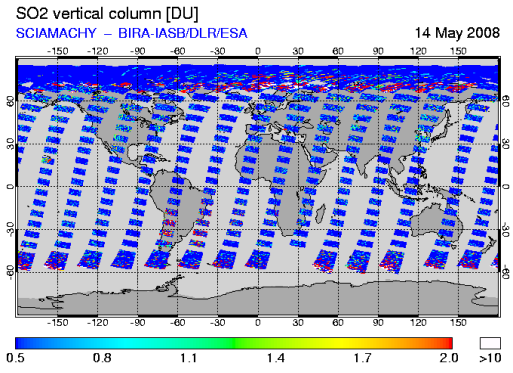

Figure 9. Example of Volcanic Gas Emission (SO_2) prodct obtained by processing SCIAMACHY data (2008-05-14).

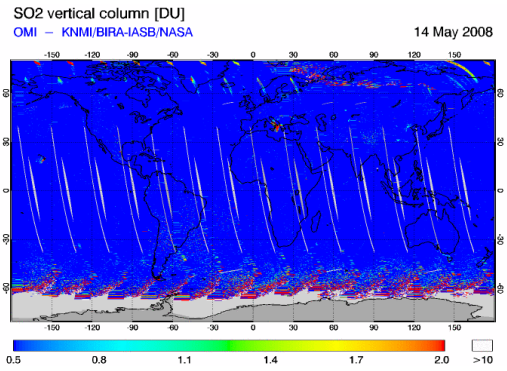

Figure 10. Example of Volcanic Gas Emission (SO_2) prodct obtained by processing OMI data (2008-05-14).

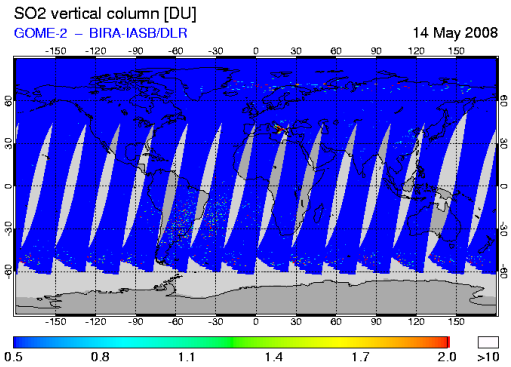

Figure 11. Example of Volcanic Gas Emission (SO_2) prodct obtained by processing GOME-2 data (2008-05-14).

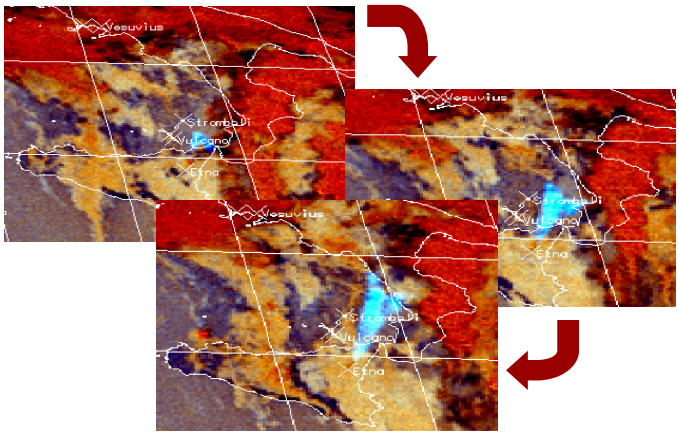

Figure 12. Etna (Sicily) - Example of Volcanic Ash Tracking product obtained by processing three successive MSG – SEVIR scene (2008-05-13).

V. PHASE 2 ACTIVITIES

The second phase of the project concerns EO products generation and delivery on pre-operational basis over about 15 volcano sites.

The User Organizations and Volcanoes involved during phase 2 activities are graphically represented in Fig. 13. The picture shows the geographic distribution of the volcano sites.

The phase 2 volcanoes represent a worldwide selection, thus ensuring a global coverage. These volcanoes are characterized by different eruptive style and volcanic features.

The service cases were defined according to the following criteria:

- Users' requests
- Availability of EO data
- Feasibility constraints
- Presence of urban centre(s)

The Volcanoes selected for the second phase of the project will represent an exhaustive mix of volcano typologies in order to assess the capability and the limits of the EO-based information services and methodologies proposed.

The User Organizations involved during this phase will integrate GlobVolcano products in their working environment and provide GlobVolcano team with an evaluation about the usefulness o f the products.

A Best Practice Guideline will be defined on the basis of needs and experience of each User Organization involved.

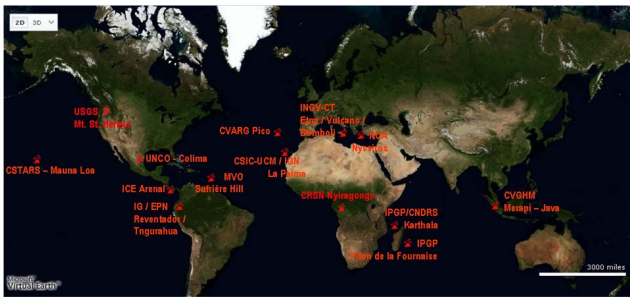

Figure 13. Glob Volcano phase 2 User Organisations and volcanoes (preliminary)