



EUROPEAN
COMMISSION

Community Research



Grant Agreement number:	263502 Collaborative Project
Project acronym	PRE-EARTHQUAKES
Project title	Processing Russian and European EARTH observations for earthQUAKE precursors Studies
Funding Scheme:	SEVENTH FRAMEWORK PROGRAMME - FP7-SPACE-2010-1
Thematic Priority	SPA.2010.3.2-01 - EU-Russia Cooperation in GMES (SICA)
Project starting date:	01 January 2011
Project duration:	24 months
Project coordinator:	UNIBAS Valerio.tramutoli@unibas.it

Report On Major Earthquakes (And Quiescent Period): updated version after KoM

Deliverable reference number	PREQ-D30.31
Date of deliverable	04/05/2011
Issue. Revision	0.2.
Name and Organisation responsible for this deliverable	TUBITAK MAM
Names and Organisation of partners contributing for this deliverable	UNIBAS, DLR, TUBITAK MAM, FIAG, RSS, WDIZMIRAN

Project co-funded by the European Commission within the Seventh Framework Programme

Dissemination Level : PU

PU	Public
PP	Restricted to other programme participants (including the Commission Services)
RE	Restricted to a group specified by the consortium (including the Commission Services)
CO	Confidential, only for members of the consortium (including the Commission Services)

CHANGE RECORDS

Issue	Date	Pages	Changes
0.1			First draft

REFERENCE DOCUMENTS

Ref. / Document Title	Document Number	Issue	Date
R1. Grant Agreement Annex I - "Description of work"	263502 Annex I	1.0	22.10.2010
R2. Report On Major Earthquakes (And Quiescent Period)	Deliverable PREQ-D30.3	0.1	28/02/2011
R3.			
R4.			
R5.			

TABLE OF CONTENTS

1	Introduction	5
2	Scope of the document	5
3	Seismicity of main test areas	7
3.1	Earthquakes of the Italian peninsula	7
3.1.1	Abruzzo Earthquake (6 April 2009, Mw 6.3)	7
3.1.2	Molise earthquake (31 October 2002, Mw 5.9)	7
3.1.3	Umbria-Marche earthquakes (26 September 1997, Mw 6.0).....	8
3.2	Earthquakes of Turkey	8
3.2.1	Elâzığ Earthquake (8 March 2010, Mw 6.1)	8
3.2.2	Izmit earthquake (17 August 1999, Mw 7.7).....	8
3.3	Earthquakes of Sakhalin island.....	9
3.3.1	Nevelsk Earthquake (2 August 2007, Mw 6.2) and Ulegorsk earthquake (4 August 2000, Mw 6.8) 9	
4	Additional test cases	9
4.1	Kaliningrad earthquake (21 September 2004, Mw 5.2).....	9
4.2	Tohoku (Sendai) earthquake (11 March 2011, Mw 9.0)	10
4.3	Greece events.....	10
5	Conclusions	11
6	References	11
7	Annex 1	13

FIGURES

Figure 1 Location of test areas.

TABLES

- Table 1 Geographical limits of test areas.
- Table 2 List of principal events of Abruzzo earthquake.
- Table 3 List of principal events of Molise earthquake.
- Table 4 List of principal events of Umbria-Marche sequence.
- Table 5 List of principal events of Elâziğ Earthquake.
- Table 6 List of principal events of Izmit earthquake.
- Table 7 List of principal events of Nevelsk Earthquake
- Table 8 List of principal events of Uglegorsk earthquake.
- Table 9 List of principal events of Kaliningrad earthquakes.
- Table 10 List of principal events of Tohoku (Sendai) earthquakes.
- Table 11 List of principal events of Greece.
- Table 12 Main selected test-cases.

1 Introduction

This deliverable is an output of Task 30.20 as part of the WP 30 (Integration and Cross Validation) activities. The scope of WP 30 is the integration of different data products originated by partners (in the framework of WP 20 activities) using different data and methodologies. To this aim common I/O format will be defined as well as suitable validation/confutation procedures for the assessment of possible space-time relationships among selected (or joint) parameters variations and earthquake occurrence.

Task 30.20 (Off-line test cases preparation, Task Leader: TUBITAK) is devoted to the selection, for each of the 3 identified test areas (Italy, Turkey, Sakhalin region) of time periods in the past, suitable for:

- validation (i.e. including significant earthquakes)
- confutation (i.e. without any significant earthquakes)
- the availability of the major number of independent observations of potential precursors to be jointly analyzed (integration).

All partners contributed to this task for the part relative to their data products. UNIBAS (for Italy), TUBITAK (for Turkey), RSS (for Sakhalin region) made the first selection of major earthquakes in the past to be considered for validation/confutation procedures. All the other partners provided information on the availability of relevant observations for these preliminarily selected test-cases. The Project Coordinator supported the Task Leader (TUBITAK, who is also the responsible of this deliverable) in order to make a pre-selection of the best test-case for each of the selected testing areas on the base of pre-selected quality indicators.

This second version of deliverable PREQ-D30.3 take into account also the results of specific Working Group of the kick-off meeting (Potenza, 15-16 March 2011), regarding the possibility to include some additional events particularly interesting even if outside the initially planned testing areas.

2 Scope of the document

The purpose of this document is to identify the most suitable test cases to be analyzed off-line in the PRE-EARTHQUAKES project. In order to identify these events, three main testing areas (Fig. 1), have been firstly considered:

- ✓ Italian peninsula;
- ✓ Turkish region;
- ✓ Sakhalin island.

Moreover the following additional criteria have been used in order to select the events most suitable for the scope of the project:

- ✓ availability of the major number of independent observations (parameters, technologies, methodologies) both for validation and confutation purposes
- ✓ most recent higher event intensity

Following these criteria and considering also the discussions of the specific Working Group of kick-off meeting (Test-cases WG), other region have been considered as a

possible (additional) testing area. These areas will be considerate in the PRE-EARTHQUAKES project as test area of minor interesting. The region considerate have been:

- ✓ the Kaliningrad district;
- ✓ the Japan island;
- ✓ the Greece peninsula.

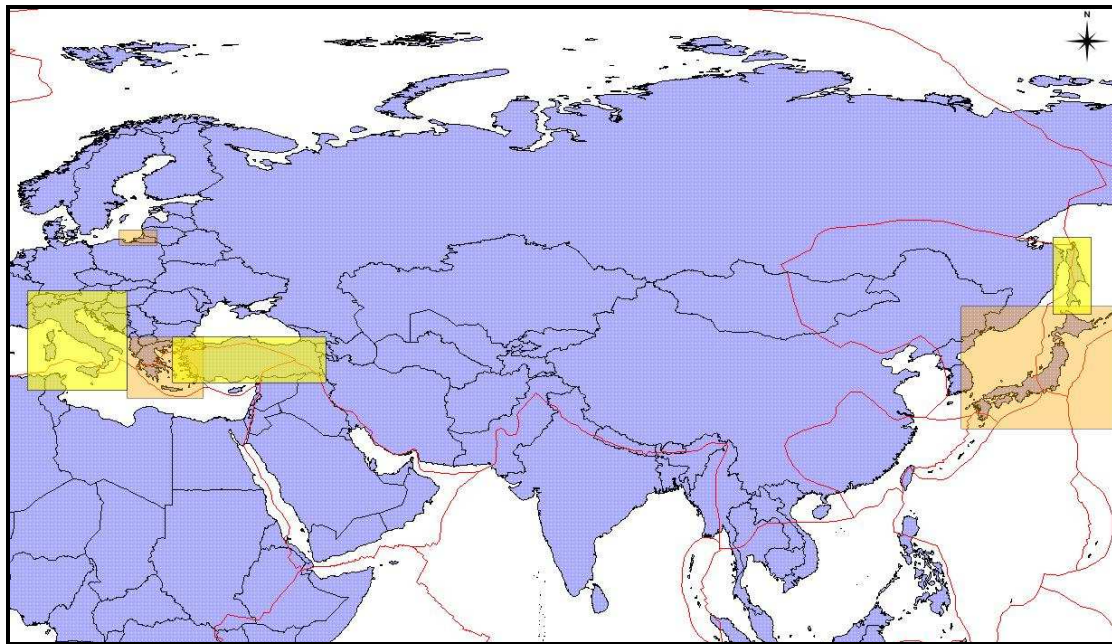


Figure 1. Location of test areas. The yellow boxes indicate the principal regions to investigate, the orange boxes additional region to investigates and considered as secondary test-area, red line symbolize the tectonic plate boundaries.

For the selected areas, in order to define the test-cases, the following seismic catalogue, free available online, have been preliminarily consulted:

- ✓ for Italy the INGV catalogue:
 - for earthquakes after 2002 the Italian Seismic Bulletin available on INGV web site (<http://bollettinosismico.rm.ingv.it/>) and ISIDe service (Italian Seismic Instrumental and parametric Data-basE) have been consulted;
 - for earthquakes before 2002 the Seismic Bulletin 1983-2004 (BS) and the Catalogue of the Italian Seismicity 1981-2002 (CSI 1.1), both available on line at web site <http://iside.rm.ingv.it/iside/standard/index.jsp> have been used;
- ✓ for Turkey, Sakhalin and other region the IRIS (Incorporated Research Institutions for Seismology) service accessible on <http://www.iris.edu/servlet/eventserver/map.do>, the ANSS (Advanced National Seismic System) catalogue available on <http://www.ncedc.org/anss/catalog-search.html>, and USGS National Earthquake Information Center (NEIC) service accessible on web site <http://earthquake.usgs.gov/earthquakes/eqarchives/epic/> have been consulted.

The geographical limits of the area to be investigated have been identified as reported in Table 1.

Test case area	Min latitude (N)	Max latitude (N)	Min longitude (E)	Max longitude (E)
ITALY	35° 00'	48° 00'	6° 00'	19° 00'
TURKEY	36° 00'	42° 00'	25° 00'	45° 00'
SAKHALIN	45° 00'	55° 00'	140° 00'	145° 00'
KALININGRAD	54° 00'	56° 00'	18° 00'	23° 00'
JAPAN	30° 00'	46° 00'	128° 00'	148° 00'
GREECE	34° 00'	42° 00'	19° 00'	29° 00'

Table 1. Geographical limits of test areas.

3 Seismicity of main test areas

3.1 Earthquakes of the Italian peninsula

3.1.1 Abruzzo Earthquake (6 April 2009, Mw 6.3)

The Abruzzo earthquake (Mw~6.3) occurred on 6 April 2009 at 01:32:39 GMT, having its epicentre at 42.348N and 13.380E. The earthquake of 6 April 2009 was the largest event in a seismic sequence that started a few months earlier and had its most significant previous event on 30 March 2009 (Mw~4.4). During the days following the main event about 30 earthquakes with $M_l \sim 3.5 \div 5$ and several thousand events of lower magnitude were registered.

Date	Lat. (N)	Long. (E)	Mw
2009/03/30	42.326	13.362	4.4
2009/04/06	42.348	13.380	6.3
2009/04/07	42.275	13.464	5.6
2009/04/09	42.484	13.343	5.4

Table 2. List of principal events of Abruzzo earthquake. Green row indicate the mainshock.

3.1.2 Molise earthquake (31 October 2002, Mw 5.9)

The Molise earthquake (Mw~5.9) struck the Molise region in southern Italy on 31 October 2002 at 10:32 GMT, having its epicentre at 41.692N and 14.913E. This event was followed by a second shock of a similar magnitude (Mw~5.7) on 1 November 2002 at 15:08 GMT, having its epicentre at 41.820N and 14.820E. Both events having the similar properties, the earthquake hypocenters were located at mid-crust depth ($18 \div 22$ km) and the mechanisms were almost pure strike slip (Vallée and Di Luccio, 2005). These events have triggered a swarm-like sequence (about 1900 earthquakes with $M_l \sim 2 \div 4$) that lasted for several days.

Date	Lat. (N)	Long. (E)	Mw
2002/10/31	41.692	14.913	5.9
2002/11/01	41.820	14.820	5.7

Table 3. List of principal events of Molise earthquake. Green row indicate the mainshock.

3.1.3 Umbria-Marche earthquakes (26 September 1997, Mw 6.0)

The 1997 Umbria-Marche seismic sequence consists of 6 earthquakes, with magnitudes (Mw) between 5 and 6, and about 2000 aftershock that in 40 days struck Central Italy (Antonoli et al, 2005). The active period began on 3 September 1997 with a Mw~4.5 event followed by a relatively low level of seismic activity. The major part of the crisis developed after 26 September when two earthquakes with Mw~5.7 and Mw~6.0 occurred in the Colfiorito area. Two more events (Mw~5.2 and Mw~5.4) occurred in the same area on 3 and 6 October. The last two significant events (Mw~5.2 and Mw~5.6) occurred 15 km to the south-east, on 12 and 14 October. On 3 April 1998, a seismic event with Mw~5.1 occurred in the northern sector of seismic zone (Deschamps et al, 2000).

Date	Lat. (N)	Long. (E)	Mw
1997/09/26	43,018	12,913	5.7
1997/09/26	43,024	12,926	6.0
1997/10/03	43,023	12,89	5.2
1997/10/06	43,01	12,918	5.4
1997/10/12	42,897	13,008	5.2
1997/10/14	42,907	12,969	5.6
1998/03/26	43.145	12.809	5.4
1998/04/03	43,177	12,786	5.1

Table 4. List of principal events of Umbria-Marche sequence.

3.2 Earthquakes of Turkey

3.2.1 Elâzığ Earthquake (8 March 2010, Mw 6.1)

On 8 March 2010, Elazığ earthquake of magnitude Mw 6.1 occurred at 04:32 (02:32 GMT) local time. It's located (epicentral coordinates 38.7752N-40.0295E) in a high seismicity region on Eastern Anatolian Fault System (EAFS). Being one of the most seismically active zones in Turkey, Elazığ settles on the East Anatolian Fault (EAF), almost at the north-eastern end, where EAF meets the well known North Anatolian Fault (NAF) at the Karlıova triple junction. Until March 18, a number of 275 aftershock are recorded pursuing the main event on 8 March 2010, including four of them with magnitudes $M_l > 5.0$, the major aftershock of $M_l \sim 5.6$ occurred on 8 March 2010 at 07:47GMT having the epicentral coordinates at 38.7355N-40.0090E caused damages in Palu district (Celap et al, 2011).

Date	Lat. (N)	Long. (E)	Mw
2010/03/08	38.7752	40.0295	6.1
2010/03/08	38.7355	40.0090	5.8

Table 5. List of principal events of Elâzığ Earthquake. Green row indicate the mainshock.

3.2.2 Izmit earthquake (17 August 1999, M_l 7.7)

On 17 August 1999 the Izmit earthquake ($M_l \sim 7.7$) occurred at 00:01:39 UTC (3:01 a.m. local time), and was centered at 40.74 N, 29.86 E, which places the epicenter about 11 kilometers, southeast of the city of Izmit. This location indicates that the earthquake occurred on the northernmost strand of the North Anatolian fault system. The earthquake originated at a depth of 17 kilometers, and caused right-lateral strike-slip movement on the fault system. This event was the seventh in a sequence of westward migrating earthquakes along the NAF (North Anatolian Fault) since 1939. Followed the mainshock,

on 19 August at 14:16 and 15:18 UTC (5:16 and 6:18 PM local time), two light-to-moderate earthquakes with magnitudes of 4.8 and 5.0 occurred approximately 80 km to the west of the mainshock.

Date	Lat. (N)	Long. (E)	MI
1999/08/17	40.743	29.862	7.7
1999/08/19	40.601	29.149	4.8
1999/08/19	40.618	29.138	5.0

Table 6. List of principal events of Izmit earthquake. Green row indicate the mainshock.

3.3 Earthquakes of Sakhalin island

3.3.1 Nevelsk Earthquake (2 August 2007, Mw 6.2) and Ulegorsk earthquake (4 August 2000, Mw 6.8)

On 2 August 2007, at 02:37 UTC (13:37 Sakhalin time), a strong earthquake of Mw=6.2 occurred in the Tatar Strait basin, having its epicentre at 47.259N and 141.750E. A numerous aftershocks (about 1350) during the first week were occurred. The majority of the aftershocks of the Nevelsk earthquake defines an epicentral region in the southwestern Sakhalin shelf (SWS) seismogenic zone. The magnitude of the strongest aftershock (Mw~5.8), which occurred in the first hours, was close to the magnitude of the main shock (Mw~ 6.2), suggesting the occurrence of paired earthquakes (Kim et al, 2009). The main shock occurred at a depth of 10 km, while most of the aftershocks were accumulated at depths of less than 5 km.

Date	Lat. (N)	Long. (E)	Mw
2007/08/02	47.259	141.750	6.2
2007/08/02	46.714	141.722	5.8
2007/08/14	46.877	141.746	5.5

Table 7. List of principal events of Nevelsk Earthquake. Green row indicate the mainshock.

On 4 August 2000, Ulegorsk earthquake (Mw~6.8) occurred near the west coast of Sakhalin, having its epicenter at 48,786N and 142,246E. It's the largest instrumentally recorded dip-slip event on the island (Kogan et al, 2003).

Date	Lat. (N)	Long. (E)	Mw
2000/08/04	48,786	142,246	6.8
2000/08/04	48.922	142.113	5.3
2000/08/10	48.732	141.258	5.2

Table 8. List of principal events of Ulegorsk earthquake.

4 Additional test cases

4.1 Kaliningrad earthquake (21 September 2004, Mw 5.2)

On 21 September 2004, two seismic events are occurred in the territory of the Russian Kaliningrad enclave. This area is considered as a low-seismicity area, in fact in the Baltic Sea region the maximum earthquake magnitudes well below 6. The first earthquake occurred (Mw~5.0) at 11:05 GMT, having its epicentre at 54.908N and 20.029E. The second and largest earthquake (Mw~5.2) occurred at 13:32 UTC, its epicentre has been

at 54.849N and 20.088E, a small aftershock followed the second event 4 minutes later (Gregersen et al, 2007). The earthquake hypocenters were located at 16–20 km depth, and focal mechanisms of clear strike-slip type rule out blast as the cause of the events.

Date	Lat. (N)	Long. (E)	Mw
2004/09/21	54.908	20.029	5.0
2004/09/21	54.849	20.088	5.2

Table 9. List of principal events of Kaliningrad earthquakes.

4.2 Tohoku (Sendai) earthquake (11 March 2011, M 9.0)

On 11 March 2011, at 14:46 LT (05:46 GMT), a strong earthquake of magnitude 9.0 occurred near the northeast coast of Japan, resulted from thrust faulting on or near the subduction zone plate boundary between the Pacific and North America plates (USGS 2011). The epicentre of the earthquake is located 400 km away from the capital Tokyo at a depth of 32 km. The Tohoku (Sendai) earthquake was preceded by a series of large foreshocks over the previous two days, beginning on 9 March with a M 7.2 event approximately 40 km from the epicenter of the 11 March seismic event, and continuing with another three earthquakes greater than M 6 on the same day.

Date	Lat. (N)	Long. (E)	M
2011/03/09	38,435	142,842	7.2
2011/03/11	38,301	142,38	9.0
2011/03/11	36,27	141,145	7,9
2011/03/11	38,058	144,591	7,7
2011/03/11	37,594	142,648	6,5
2011/03/22	39,852	143,418	6,4

Table 10. List of principal events of Tohoku (Sendai) earthquakes.

4.3 Greece events

For the particular tectonic location, the Greece region has considered as possible testing area, in fact in the eastern Mediterranean area the earth's crust and lithosphere constitute a broad boundary region between three major tectonic plates, the Eurasia, Africa, and Arabia plates. The motions of these major plates drive smaller microplates, and it is the shapes and motions of these smaller plates that determine the locations and focal mechanisms of most intraplate earthquakes in the region. In the last years various earthquakes (with magnitudes greater than 6) occurred in this area. In table 11 are reported some of these events.

Date	Lat. (N)	Long. (E)	Mw
2006/01/08	36,31	23,21	6,7
2008/01/06	37,22	22,69	6,2
2008/02/14	36,50	21,67	6,9
2008/02/14	36,35	21,86	6,5
2008/02/20	36,29	21,77	6,2
2008/06/08	37,96	21,52	6,4
2008/07/15	35,80	27,86	6,4
2009/07/01	34,16	25,47	6,4
2011/04/01	35,72	26,55	6,1

Table 11. List of Greece events.

5 Conclusions

Considering the information provided by all partners and reported in the first version of this deliverable (Deliverable PREQ-D30_3) and on the basis of the considerations provided during the specific Working Groups of the kick-off meeting devoted to select the test cases, we highlight two orders of priority, which:

1. most important events (i.e. earthquakes occurred in the PRE-EARTHQUAKES testing area);
2. secondary events (i.e. earthquakes outside the PRE-EARTHQUAKES testing area, but interesting to study for the possibility to use specific observation available only for some events).

In agreement with the selection criteria described in chapter 2, the primary events to study in the PRE-EARTHQUAKES project are reported in table 12.

Test case event		Period to analyze for validation purposes	Number of independents observations	Number of parameters	Number of Methodologies	Period to analyze for confutation purposes
ITALY	Abruzzo EQ 6 Apr 2009 MI 5,8	March/April 2009	6	7	5	March/April 2007 (n.2 EQs M>4; n.0 M>5)
TURKEY	Elâzığ EQ 8 Mar 2010 Mw 6,1	February/March 2010	7	9	3	February/March 2006 (n.5 EQ M>4; n.0 EQ M>5)
SAKHALIN	Nevelsk EQ 2 Aug 2007 Mw 6.2	July/August 2007	7	6	5	July/August 2008 (n.0 EQ M>4; n.0 EQ M>5)

Table 12. Main selected test-cases.

6 References

- Antonioli A., Piccinini D., Chiaraluce L. and Cocco M. (2005). *Fluid flow and seismicity pattern: Evidence from the 1997 Umbria-Marche (central Italy) seismic sequence*. Geophysical Research Letters, 32, L10311.
- Celep Z., Erken A., Taskin B. and Ilki A. (2010, in press). *Failures of masonry and concrete buildings during the March 8, 2010 Kovancilar and Palu (Elazig) Earthquakes in Turkey*. Engineering Failure Analysis, doi:10.1016/j.engfailanal.2010.11.001.

- Deschamps A., Courboux F., Gaffet S., Lomax A., Virieux J., Amato A., Azzara A., Castello B., Chiarabba C., Cimini G.B., Cocco M., Di Bona M., Margheriti L., Mele F., Selvaggi G., Chiaraluce L., Piccinini D. and Ripepe M. (2000). *Spazio-temporal distribution of seismic activity during the Umbria-Marche crisis, 1997*. Journal of Seismology, 4, 377-386.
- Gregersen S., Wiejacz P., Debski W., Domanski B., Assinovskaya B., Guterch B., Mantyniemi P., Nikulin V.G., Pacesa A., Puura V., Aronov A.G., Aronova T.I., Grunthal G., Husebye E.S. and Sliupa S (2007). *The exceptional earthquakes in Kaliningrad district, Russia on September 21, 2004*. Physics of the Earth and Planetary Interiors, 164, 63-74.
- Kim Ch.U., Mikhailov V.I., Sen R.S. and Semenova Ye.P. (2009). *The August 2, 2007, Nevsk Earthquake: Instrumental Data Analysis*. Russian Journal of Pacific Geology, 3, 5, 412-423.
- Kogan M.G., Burgmann R., Vasilenko N.F., Scholz C.H., King R.W., Ivashchenko A.I., Frolov D.I., Steblov G.M., Kim Ch.U. and Egorov S.G. (2003). *The 2000 Mw 6.8 Ulegorsk earthquake and regional plate boundary deformation of Sakhalin from geodetic data*. Geophysical Research Letters, 30, 3, L1102.
- USGS (2011). <http://earthquake.usgs.gov/earthquakes/eqinthenews/2011/usc0001xqp/#summary>
- Vallée M. and Di Luccio F. (2005). *Source analysis of the 2002 Molise, southern Italy, twin earthquakes (10/31 and 11/01)*. Geophysical Research Letters, 32, L1230.

7 Annex 1

Test case event		Period to analyze for validation purposes	Number of independents observations	Number of Parameters	Number of Methodologies	Period to analyze for confutation purposes
ITALY	Abruzzo EQ 6 Apr 2009 MI 5,8	March/April 2009	6	7	5	march/april 2001 (n.1 EQ M>4; n.0 EQ M>5)
						march/april 2004 (n.1 EQ M>4; n.0 EQ M>5)
						march/april 2007 (n.2 EQs M>4; n.0 M>5)
						march/april 2010 (n.1 EQ M>4; n.0 EQ M>5)
	Molise EQ 31 Oct 2002 Mw 5,9	October/November 2002	6	4	4	october/november 1992 (n.1 EQ M>4; n.0 EQ M>5)
						october/november 1998 (n.0 M>4; n.0 EQ M>5)
						october/november 2000 (n.0 EQ M>4; n.0 EQ M>5)
	Umbria-Marche EQs 16 September 1997 Mw 6,1	September/October 1997 and March 1998	4	2	3	sep/oct 1992 (n.1 EQ M>4; n.0 EQ M>5) march 1992 (n.0 EQ M>4; n.0 EQ M>5)
						sep/oct 1993 (n.2 EQs M>4; n.0 EQs M>5) march 1993 (n.0 EQ M>4; n.0 EQ M>5)
						sep/oct 1994 (n.2 EQs M>4; n.0 EQs M>5) march 1994 (n.2 EQs M>4; n.0 EQ M>5)
						sep/oct 1999 (n.4 EQs M>4; n.0 EQ M>5) march 1999 (n.1 EQ M>4; n.0 EQ M>5)
						sep/oct 2001 (n.3 EQs M>4; n.0 EQ M>5) march 2001 (n.1 EQ M>4; n.0 EQ M>5)
						feb/march 2006 (n.5 EQ M>4; n.0 EQ M>5)
TURKEY	Elâzığ EQ 08 March 2010 Mw 6,1	February/March 2010	7	9	3	feb/march 2008 (n.7 EQ M>4; n.0 EQ M>5)
						feb/march 2009

						(n.3 EQs M>4; n.1 EQ M>5)
	Izmit EQ 17 August 1999 MI 7,7	August/September 1999	4	3	2	august/september 1992 (n.6 EQ M>4; n.0 EQ M>5)
						august/september 1993 (n.3 EQ M>4; n.1 EQ M>5)
						august/september 1994 (n.6 EQs M>4; n.0 EQ M>5)
						august/september 1998 (n.4 EQ M>4; n.0 EQ M>5)
SAKHALIN	Nevelsk EQ 2 Aug 2007 Mw 6.2	July/August 2007	7	6	5	july/august 2005 (n.0 EQ M>4; n.0 EQ M>5)
						july/august 2008 (n.0 EQ M>4; n.0 EQ M>5)
						july/august 2009 (n.1 EQ M >4; n.0 EQ M>5)
	Uglegorsk EQ 4 Aug 2000 Mw 6.8	July/August 2000	3	2	2	july/august 2005 (n.0 EQ M>4; n.0 EQ M>5)
						july/august 2008 (n.0 EQ M>4; n.0 EQ M>5)
						july/august 2009 (n.1 EQ M>4; n.0 EQ M>5)
OTHER	Kaliningrad EQ 21 Sept 2004 Mw 5.2	September 2004	5	4	4	september 2005 (n.1 EQ M>3; n.0 EQ M> 5)
						september 2006 (n.0 EQ M>3; n.0 EQ M>5)
						september 2007 (n.0 EQs M>3; n.0 M>5)

TEST CASE 1: Abruzzo earthquake (6 April 2009, MI 5,8)

Validation												
march/april 2009 (n.27 EQs with magnitudes >4; n.6 EQs with magnitude > 5)	partner	UNIBAS	UNIBAS	UNIBAS	FIAG	FIAG	FIAG	DLR	DLR	WD IZMIRAN	WD IZMIRAN	WD IZMIRAN
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies	GPS TEC time series	GPS TEC map	GPS TECvariab index	TEC-Map	Ne-Profile	GPS TEC daily variation	Ne Profile	GPS TEC maps
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR	GNSS GPS sat	GNSS GPS sat	GNSS GPS sat	GPS groundbased	CHAMP	GPS ground based	COSMIC	GPS ground based
	data analysis methodologies	RST	RST	RST	Ciraolo algorithm	Kriging	Pulinets algorithm	dlr	dlr			
Confutation												
march/april 2007 (n.2 EQs with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS	UNIBAS	FIAG	FIAG	FIAG	DLR	DLR	WD IZMIRAN	WD IZMIRAN	WD IZMIRAN
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies	GPS TEC time series	GPS TEC map	GPS TECvariab index	TEC-Map	Ne-Profile	GPS TEC daily variation	Ne Profile	GPS TEC maps
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR	GNSS GPS sat	GNSS GPS sat	GNSS GPS sat	GPS groundbased	CHAMP	GPS ground based	COSMIC	GPS ground based
	data analysis methodologies	RST	RST	RST	Ciraolo algorithm	Kriging	Pulinets algorithm	dlr	dlr			

TEST CASE 2: Elâziğ Earthquake (08 March 2010 Mw 6,1)

Validation												
february/march 2010 (n.11 EQ with magnitudes >4; n.5 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS	UNIBAS	FIAG	FIAG	FIAG	TUBITAK	WD IZMIRAN	WD IZMIRAN	WD IZMIRAN	
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies	particle fluxes	ion composition	GPS MET map	geochemical monitoring data (radon and spring water)	GPS TEC daily variation	Ne Profile	GPS TEC maps	
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR	METEOR GGAK	METEOR RIMS	GNSS GPS sat		GPS ground based	COSMIC	GPS ground based	
	data analysis methodologies	RST	RST	RST			IONEX					
Confutation												
february/march 2006 (n.5 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS	UNIBAS	FIAG	FIAG	FIAG	TUBITAK	WD IZMIRAN	WD IZMIRAN	WD IZMIRAN	
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies	particle fluxes	ion composition	GPS MET map	geochemical monitoring data (radon and spring water)	GPS TEC daily variation	Ne Profile	GPS TEC maps	
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR	METEOR GGAK	METEOR RIMS	GNSS GPS sat		GPS ground based	COSMIC	GPS ground based	
	data analysis methodologies	RST	RST	RST			IONEX					

TEST CASE 3: Nevseki earthquake (2 August 2007, Mw 6,2)

Validation												
july/august 2007 (n.27 EQs with magnitudes >4; n.5 EQs with magnitude > 5; n.1 EQ with magnitude>6)	partner	UNIBAS	UNIBAS	RSS	FIAG	FIAG	DLR	WD IZMIRAN	WD IZMIRAN			
	parameters monitored	TIR anomalies	TIR anomalies	EC anomalies	GPS TEC time series	GPS TECvariab index	Ne-Profile	GPS TEC daily variation	GPS fluctuation activity			
	observing technologies	EOS-MODIS	NOAA-AVHRR	RB 150/400 MHz	GNSS GPS sat	GNSS GPS sat	CHAMP	GPS ground based	GPS ground based			
	data analysis methodologies	RST	RST	tomo	Ciraolo algorithm	Pulinets algorithm	dlr					
Confutation												
july/august 2008 (n.0 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS	RSS	FIAG	FIAG	DLR	WD IZMIRAN	WD IZMIRAN			
	parameters monitored	TIR anomalies	TIR anomalies	EC anomalies	GPS TEC time series	GPS TECvariab index	Ne-Profile	GPS TEC daily variation	GPS fluctuation activity			
	observing technologies	EOS-MODIS	NOAA-AVHRR	RB 150/400 MHz	GNSS GPS sat	GNSS GPS sat	CHAMP	GPS ground based	GPS ground based			
	data analysis methodologies	RST	RST	tomo	Ciraolo algorithm	Pulinets algorithm	dlr					

TEST CASE 4: Kaliningrad earthquake (21 September 2004, Mw 5,2)

Validation							
september 2004 (n.0 EQs with magnitudes >4; n.2 EQs with magnitude > 5)	partner	UNIBAS	UNIBAS	UNIBAS	WD IZMIRAN	FIAG	DLR
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies	TEC anomalies	GPS MET map	Ne-Profile
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR	GPS	GNSS GPS sat	CHAMP
	data analysis methodologies	RST	RST	RST		IONEX	dlr
Confutation							
september 2005 (n.1 EQ with magnitudes >3; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS	UNIBAS	WD IZMIRAN		
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies	TEC variations		
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR	GPS		
	data analysis methodologies	RST	RST	RST			
september 2006 (n.0 EQ with magnitudes >3; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies			
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR			
	data analysis methodologies	RST	RST	RST			
september 2007 (n.0 EQs with magnitudes >3; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies			
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR			
	data analysis methodologies	RST	RST	RST			
september 2008 (n.0 EQ with magnitudes >3; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies			
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR			
	data analysis methodologies	RST	RST	RST			
september 2009 (n.0 EQ with magnitudes >3; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies			
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR			
	data analysis methodologies	RST	RST	RST			
september 2010 (n.0 EQ with magnitudes >3; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies			
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR			
	data analysis methodologies	RST	RST	RST			

TEST CASE 5: Tohoku (Sendai) earthquake (11 March 2011, M 9,0)

Validation							
february/march 2011 (n.1 EQ with magnitude >9; n.3 EQs with magnitude >7; n.60 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS				
	parameters monitored	TIR anomalies	TIR anomalies				
	observing technologies	EOS-MODIS	NOAA-AVHRR				
	data analysis methodologies	RST	RST				
Confutation							
february/march 2006 (n.15 EQs with magnitude >5; n.0 EQs with magnitude >7)	partner	UNIBAS	UNIBAS				
	parameters monitored	TIR anomalies	TIR anomalies				
	observing technologies	EOS-MODIS	NOAA-AVHRR				
	data analysis methodologies	RST	RST				
february/march 2009 (n.12 EQs with magnitude >5; n.0 EQs with magnitude >7)	partner	UNIBAS	UNIBAS				
	parameters monitored	TIR anomalies	TIR anomalies				
	observing technologies	EOS-MODIS	NOAA-AVHRR				
	data analysis methodologies	RST	RST				

TEST CASE 6: Greece events

Validation							
EQ with magnitude Mw 6,7 on 2006/01/08	partner	UNIBAS	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies			
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR			
	data analysis methodologies	RST	RST	RST			
EQ with magnitude Mw 6,2 on 2008/01/06	partner	UNIBAS	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies			
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR			
	data analysis methodologies	RST	RST	RST			
EQ with magnitude Mw 6,9 on 2008/02/14	partner	UNIBAS	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies			
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR			
	data analysis methodologies	RST	RST	RST			
EQ with magnitude Mw 6,5 on 2008/02/14	partner	UNIBAS	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies			
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR			
	data analysis methodologies	RST	RST	RST			
EQ with magnitude Mw 6,2 on 2008/02/20	partner	UNIBAS	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies			
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR			
	data analysis methodologies	RST	RST	RST			
EQ with magnitude Mw 6,4 on 2008/06/08	partner	UNIBAS	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies			
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR			
	data analysis methodologies	RST	RST	RST			
EQ with magnitude Mw 6,4 on 2008/07/15	partner	UNIBAS	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies			
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR			
	data analysis methodologies	RST	RST	RST			
EQ with magnitude Mw 6,4 on 2009/07/01	partner	UNIBAS	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies			
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR			
	data analysis methodologies	RST	RST	RST			
EQ with magnitude Mw 6,1 on 2011/04/01	partner	UNIBAS	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies			
	observing technologies	MSG-SEVIRI	EOS-MODIS	NOAA-AVHRR			
	data analysis methodologies	RST	RST	RST			

TEST CASE 7: Umbria-Marche earthquakes (16 September 1997, Mw 6,1)						
Validation						
september/october 1997 (n.30 EQs with magnitudes >4; n.6 EQs with magnitude > 5)	partner	UNIBAS	UNIBAS	FIAG		
	parameters monitored	TIR anomalies	TIR anomalies	GPS MET map		
	observing technologies	MFG-MVIRI	NOAA-AVHRR	GNSS GPS sat		
	data analysis methodologies	RST	RST	IONEX		
march 1998 (n.0 EQ with magnitudes >4; n.1 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies			
	observing technologies	MFG-MVIRI	NOAA-AVHRR			
	data analysis methodologies	RST	RST			
Confutation						
september/october 1992 (n.1 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS				
	parameters monitored	TIR anomalies				
	observing technologies	MFG-MVIRI				
	data analysis methodologies	RST				
march 1992 (n.0 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS				
	parameters monitored	TIR anomalies				
	observing technologies	MFG-MVIRI				
	data analysis methodologies	RST				
september/october 1993 (n.2 EQs with magnitudes >4; n.0 EQs with magnitude > 5)	partner	UNIBAS				
	parameters monitored	TIR anomalies				
	observing technologies	MFG-MVIRI				
	data analysis methodologies	RST				
march 1993 (n.0 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS				
	parameters monitored	TIR anomalies				
	observing technologies	MFG-MVIRI				
	data analysis methodologies	RST				
september/october 1994 (n.2 EQs with magnitudes >4; n.0 EQs with magnitude > 5)	partner	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies			
	observing technologies	MFG-MVIRI	NOAA-AVHRR			
	data analysis methodologies	RST	RST			
march 1994 (n.2 EQs with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies			
	observing technologies	MFG-MVIRI	NOAA-AVHRR			
	data analysis methodologies	RST	RST			
september/october 1999 (n.4 EQs with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies			
	observing technologies	MFG-MVIRI	NOAA-AVHRR			
	data analysis methodologies	RST	RST			
march 1999 (n.1 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies			
	observing technologies	MFG-MVIRI	NOAA-AVHRR			
	data analysis methodologies	RST	RST			
september/october 2001 (n.3 EQs with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies			
	observing technologies	MFG-MVIRI	NOAA-AVHRR			
	data analysis methodologies	RST	RST			
march 2001 (n.1 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies			
	observing technologies	MFG-MVIRI	NOAA-AVHRR			
	data analysis methodologies	RST	RST			
TEST CASE 8: Molise earthquake (31 October 2002, Mw 5,9)						
Validation						
october/november 2002 (n.19 EQs with magnitudes >4; n.2 EQs with magnitude > 5)	partner	UNIBAS	UNIBAS	UNIBAS	FIAG	
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies	GPS MET map	
	observing technologies	MFG-MVIRI	NOAA-AVHRR	EOS-MODIS	GNSS GPS sat	
	data analysis methodologies	RST	RST	RST	IONEX	
Confutation						
october/november 1992 (n.1 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS				
	parameters monitored	TIR anomalies				
	observing technologies	MFG-MVIRI				
	data analysis methodologies	RST				
october/november 1998 (n.0 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS			
	parameters monitored	TIR anomalies	TIR anomalies			
	observing technologies	MFG-MVIRI	NOAA-AVHRR			
	data analysis methodologies	RST	RST			
october/november 2000 (n.0 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS	UNIBAS		
	parameters monitored	TIR anomalies	TIR anomalies	TIR anomalies		
	observing technologies	MFG-MVIRI	NOAA-AVHRR	EOS-MODIS		
	data analysis methodologies	RST	RST	RST		

TEST CASE 9: Izmit earthquake (17 August 1999, MI 7,7)

Validation

august/september 1999 (n.89 EQs with magnitudes >4; n.5 EQs with magnitude > 5)	partner	UNIBAS	UNIBAS	WD IZMIRAN	FIAG
	parameters monitored	TIR anomalies	TIR anomalies	TEC anomalies	GPS MET map
	observing technologies	MFG-MVIRI	NOAA-AVHRR	GPS	GNSS GPS sat
	data analysis methodologies	RST	RST		IONEX

Confutation

august/september 1992 (n.6 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS			
	parameters monitored	TIR anomalies			
	observing technologies	MFG-MVIRI			
	data analysis methodologies	RST			
august/september 1993 (n.3 EQ with magnitudes >4; n.1 EQ with magnitude > 5)	partner	UNIBAS			
	parameters monitored	TIR anomalies			
	observing technologies	MFG-MVIRI			
	data analysis methodologies	RST			
august/september 1994 (n.6 EQs with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS		
	parameters monitored	TIR anomalies	TIR anomalies		
	observing technologies	MFG-MVIRI	NOAA-AVHRR		
	data analysis methodologies	RST	RST		
august/september 1998 (n.4 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS		
	parameters monitored	TIR anomalies	TIR anomalies		
	observing technologies	MFG-MVIRI	NOAA-AVHRR		
	data analysis methodologies	RST	RST		

TEST CASE 10: Ugleorsk earthquake (4 August 2000, Mw 6,8)

Validation

july/august 2000 (n.18 EQs with magnitudes >4; n.3 EQs with magnitude > 5, n.1 EQ with magnitude>6)	partner	UNIBAS	UNIBAS	FIAG	
	parameters monitored	TIR anomalies	TIR anomalies	GPS MET map	
	observing technologies	EOS-MODIS	NOAA-AVHRR	GNSS GPS sat	
	data analysis methodologies	RST	RST	IONEX	

Confutation

july/august 2005 (n.0 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS		
	parameters monitored	TIR anomalies	TIR anomalies		
	observing technologies	EOS-MODIS	NOAA-AVHRR		
	data analysis methodologies	RST	RST		
july/august 2008 (n.0 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS		
	parameters monitored	TIR anomalies	TIR anomalies		
	observing technologies	EOS-MODIS	NOAA-AVHRR		
	data analysis methodologies	RST	RST		
july/august 2009 (n.1 EQ with magnitudes >4; n.0 EQ with magnitude > 5)	partner	UNIBAS	UNIBAS		
	parameters monitored	TIR anomalies	TIR anomalies		
	observing technologies	EOS-MODIS	NOAA-AVHRR		
	data analysis methodologies	RST	RST		