Committee on Earth Observation Satellites

WGDisasters Seismic Hazards Demonstrator

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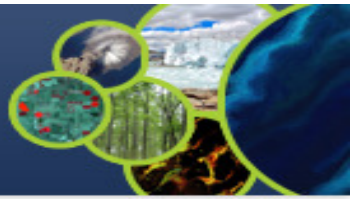
WGDisasters 18th Meeting

Nice, France

4-7 October 2022

Overview of the Demonstration Activity

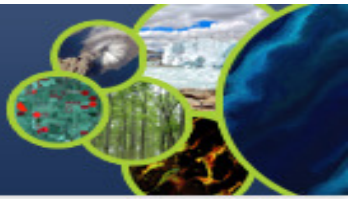


Aimed to provide satellite data for the generation of EO based, scientific information to be shared with decision makers for seismic hazards assessment.

- Pursuing **global tectonics mapping** in the long term.
- Expanding **active fault mapping** from **regional to global coverage** primarily using **VHR optical data** to support geomorphological and morpho-tectonics studies.
- Performing VHR-SAR based advanced research for earthquake response.

  ⇨ Demonstrates how satellite EO can be used to improve tectonics monitoring and earthquake response.
- Collaboration with EO based disaster response capabilities such as the International Charter Space & Major Disasters, the Copernicus EMS, and Sentinel Asia.

Data - Yearly Quotas and Consumption

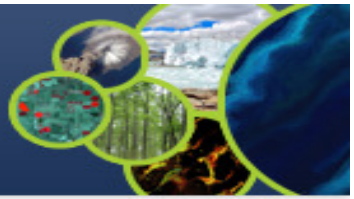


Agency	ASI Cosmo-SkyMed	CNES Pleiades	DLR TerraSAR-X	ESA Sentinel-1 & 2
Quota per year Total number of images available each year for 3 years	650 images	20000 sq. km.	Upon request	Open
Used 2019	-	20,748	-	N/A
Used 2020	24	8,947	-	N/A
Used 2021	1334	15,930	-	N/A
Total for the period	1358	45,625	-	N/A

Beneficiaries of images:

- University of Tehran
- University of Leeds
- University of Oxford
- INGV
- National Observatory of Athens (NOA)
- Aristotle University of Thessaloniki (AUTH)
- Democritus University of Thrace (DUTH)
- Comet
- British Geological Survey (BGS)
- GEM Foundation et al.
- Azerbaijan National Academy of Sciences
- Tajikistan National Academy of Sciences
- University of Central Asia
- Instituto Geofísico EPN, Ecuador
- GFZ Potsdam
- Institute of Atmospheric Physics and Seismology, Turkmenistan National Academy of Sciences
- University of Glasgow, UK

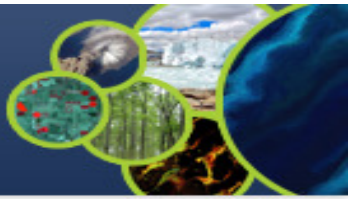
Data – Objectives and Results



Requests 2019-R01 and 2020-R13 were rejected. Requests 2019-R06, 2019-R08 and 2019-R09 weren't finalised.

Request no.	Prime Investigator Affiliation	Data requested	Location	Objective	Results
2019-R02	University of Leeds	Pleiades	Central Asia	Generate high-resolution digital elevation models, which are required to assess the natural hazards affecting urban environments.	The data allowed the requestor to engage with overseas partners in the Institute of Seismology, Bishkek, to assess disaster risk in urban environments using the data as a basis for high-resolution modeling and mapping. Retrieval of building-level city detail, which is not possible using medium resolution open access satellite data.
2019-R03	University of Leeds	Pleiades	Indonesia	Monitoring the displacement field of the 28/09/2018 earthquake Mw7.5 in Minahasa, Sulawesi, Indonesia where the earthquake and subsequent tsunami destroyed homes	Assessment of the potential of Pleiades for deriving the Palu fault rupture offsets through both the urban city and rural environment
2019-R04	University of Leeds	Pleiades	Quito, Ecuador	Derive models of multi-hazard risk (earthquakes, flooding, fire, and volcano) to inform urban development planning for major capital cities using Pleiades VHR images	Engagement with overseas partners to assess disaster risk in urban environments using the data as a basis for high-resolution modeling and mapping. Characterisation of urban exposure to hazards Collaboration is ongoing with the Municipality of Quito through the Tomorrow's Cities project to integrate products into disaster risk reduction for urban planning. Outputs were publicly exhibited in the Museo de la Ciudad and Museo Interactivo de Ciencia, Quito
2019-R05	University of Leeds	Pleiades	Kathmandu, Nepal	Derive models of multi-hazard risk (earthquakes, flooding, fire, and volcano) to inform urban development planning for major capital cities using Pleiades VHR images	Engagement with overseas partners to assess disaster risk in urban environments using the data as a basis for high-resolution modeling and mapping. Characterisation of urban exposure to hazards

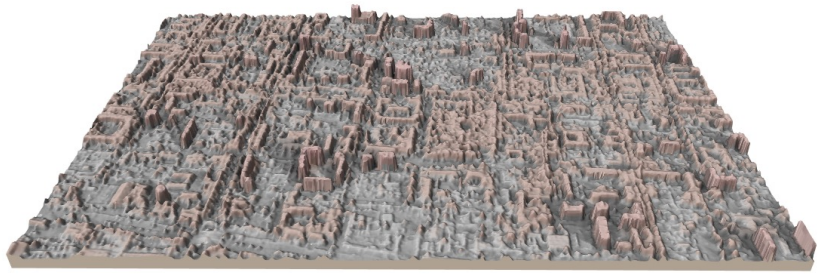
Data – Objectives and Results



Request no.	Prime Investigator Affiliation	Data requested	Location	Objective	Results
2019-R07	University of Leeds	Pleiades	Nairobi, Kenya	Deriving models of multi-hazard risk (earthquakes, flooding, fire, and volcano) to inform urban development planning for major capital cities using Pleiades VHR images	Engagement with overseas partners to assess disaster risk in urban environments using the data as a basis for high-resolution modeling and mapping. Characterisation of urban exposure to hazards
2019-R10	University of Oxford	Pleiades tri stereo	Ashgabat, Turkmenistan	Examine the landscape for signs of faulting within urban Ashgabat associated with the destructive 1948 earthquake, and to undertake reconnaissance in support of further palaeo-seismic trenching studies.	Data covered ~50% of the length of the fault in Turkmenistan. The tectonic geomorphology of important sources of earthquake hazard identification and mapping completion. The data has been combined with fieldwork to examine the distribution of faulting and to determine the source of a devastating earthquake in 1948 in Ashgabat, the capital city of Turkmenistan
2019-R11	Argans c/ESA	Cosmo-SkyMed	Durres, Albania	Retrieval of ground displacement and/or the phase using Cosmo-SkyMed.	Few results due to coherence loss but the Co-seismic fringes were retrieved
2020-R12	University of Leeds	Pleiades	Elazig, Turkey	Characterisation of the 2020 rupture along the East Anatolian Fault zone with Pleiades stereo data	No successful stereo imagery was acquired in the specified acquisition period
2020-R14	University of Oxford	Pleiades Tri-Stereo	Dushanbe, Tajikistan	Active faulting and fault behavior study combining geomorphic analysis with InSAR studies of fault slip. Seismological and geomorphic study of active faulting, and the source of the destructive 1949 Khait earthquake	The active fault zones of Tajikistan are very large. The request concerned a very small areas with particularly interesting features. Due to covid restrictions the team was not able to perform follow-up fieldwork yet, but the satellite data will be enormously valuable in guiding the field studies
2020-R15	NOA, AUTH, DUTH	Pleiades Tri-Stereo	Samos Island, Greece	Detection of co-seismic horizontal displacement and identification and mapping of the extensive landslides (active and inactive), after the earthquake occurring on 30th October 2020, in the broader area of Karlovasi, Samos Island using Pleiades tri-stereo.	Work is focused on creating a new detailed inventory of large gravitational features using Pleiades data, in the north-central area of Samos islands, around Neo Karlovassi

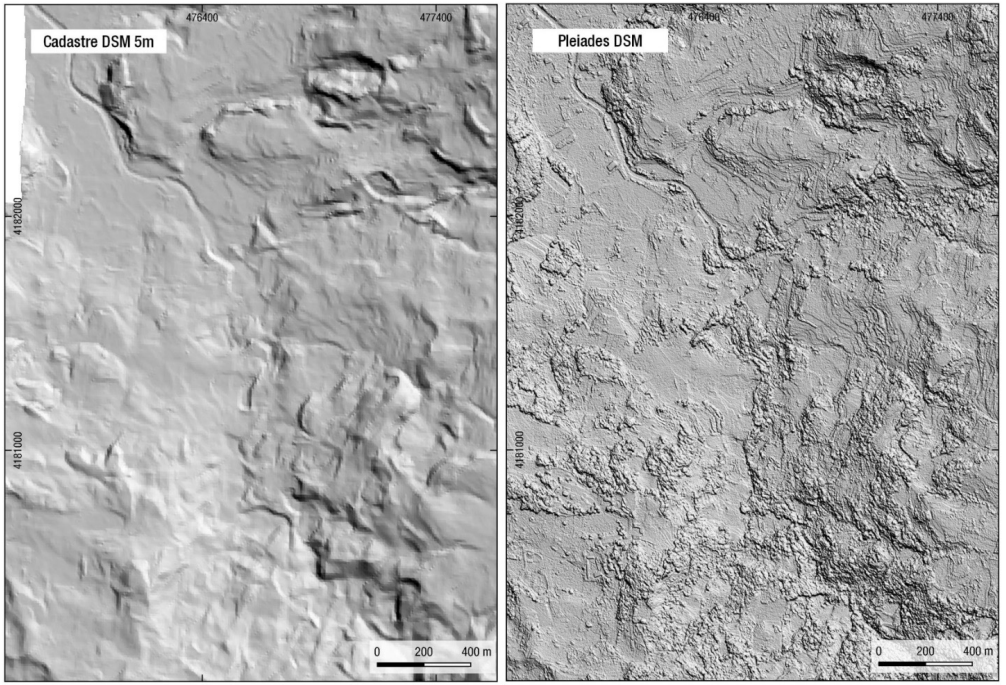
Results with Optical VHR imagery - Examples

2019-R02



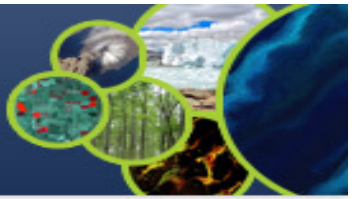
Example 3D views of buildings in central Bishkek derived using Pleiades stereo imagery data
Aim: updating exposure datasets for seismic risk modelling

2020-R15



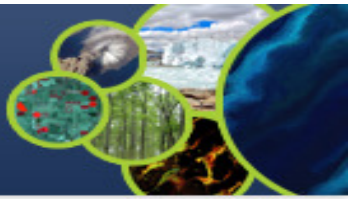
Comparison of DEMs for mapping earthquake-induced landslides due to the Samos M7.0 earthquake Greece (30 October 2020).
The Pleiades stereo and tri-stereo digital surface model (right – 1.0 m) offers more detail than the so-far best, publicly available DEM from airborne photogrammetry (left; Hellenic Cadastre – 5.0 m pixel size)
Area: Fourniotikos valley, western Samos island

Data – Objectives and Results



Request no.	Prime Investigator Affiliation	Data requested	Location	Objective	Results
2020-R16	University of Oxford	Pleiades Stereo	Dushanbe, Tajikistan	Pursuing the study of the Ilyak fault zone located at the north and east of Dushanbe	The order enabled them to cover half of Dushanbe (capital city of Tajikistan) and surrounding areas. The research team combined the data with Pleiades stereo purchased through other funding sources to produce a DEM covering the entire Dushanbe region. They have been able to identify and to map the tectonic geomorphology of important sources of earthquake hazard. They have a detailed map of the urban regions of Dushanbe. They have combined the analysis of the optical-derived DEMs with an InSAR study of strain accumulation across the major faults. Eventual aim is to combine all results into an understanding of hazard, risk, and exposure.
2021-R17	University of Oxford	Pleiades Tri-stereo	Almaty, Kazakhstan	Derive digital elevation models using Pleiades stereo data to identify and characterise active fault scarps in urban regions along the Zailisky range front in Kazakhstan, including the city of Almaty (2M population) and various other large towns (including Bishkek, Kyrgyzstan). Identifying earthquake hazards (earthquake histories and fault locations) in the Tien Shan region Building Classification for updating Exposure data.	A major active fault runs along the Zailisky rangefront. The rangefront is largely urban, which makes the identification of fault scarps difficult. The data has enabled us to map the fault zone along its length, and guided field surveys for palaeoseismic trenching.
2021-R18	University of Tehran	Cosmo-SkyMed	Tehran, Iran	Mapping inter-seismic strain accumulation over the urban area of Tehran using Cosmo-SkyMed and Comparison with Sentinel-1 and ICESAT-2 data. Monitoring the basins long term subsidence.	Data received in 2022, not yet processed
2021-R19	INGV, NOA, AUTH	Cosmo-SkyMed and CSK Second Generation	Tirnavos, Thessaly, Greece	Joint analysis processing Sentinel-1 and CosmoSkyMed for the Thessaly M6.3 in March 2021 for post seismic relaxation of the area. Retrieval of ground displacement and/or the phase using Cosmo-SkyMed in Tyrvanos	CosmoSkyMed: Few results due to coherence loss but the Coseismic fringes were retrieved. Sentinel-1: Displacement assessment (max-38cm)

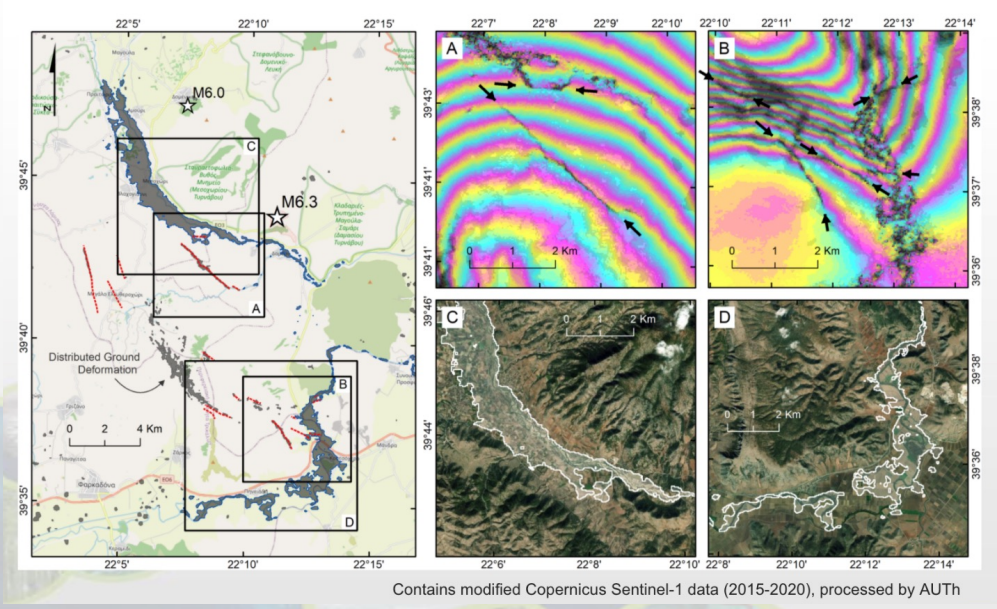
Data – Objectives and Results



Request no.	Prime Investigator Affiliation	Data requested	Location	Objective	Results
2021-R20	University of Oxford	Pleiades Stereo	Shamakhi, Azerbaijan	Using Pleiades stereo data to support active fault characterisation and paleo-seismic trenching along the edge of the Caucasus mountains and within the Kura basin, where rapid slip is expected, but evidence of active faulting is subtle	The order enabled us to cover the entire range front of the Zailisky mountains, combined with additional data purchased through a separate research grant. Together the coverage enabled the identification of previously unknown major fault systems crossing the Kura river plains and enabled us to identify sites for follow up fieldwork and palaeosesismic trenching (fieldtrip in April 2022). The results have a very large impact in the way that earthquake hazard is estimated in Azerbaijan
2021-R21	COMET-University of Leeds	Pleiades Tri-stereo	Qinghai, China	Deriving DEMs of the 2021 May 21st Mw 7.3 Maduo earthquake rupture using Pleiades tri-stereo data to map the fault rupture zone.	Some data were re-acquired in May 2022 due to artefacts in previous acquisitions.
2021-R22	COMET-University of Leeds	Pleiades Tri-stereo	Tehran, Iran	Creation of a DEM over the entire city of Tehran for geomorphic analysis of hidden faults within the city	Work began in 2022 Huge advantage in terms of much higher resolution (2 m instead of 30 m) and better DEM generation from tri-stereo imagery which is necessary in urban environments. ICESAT-2 laser altimetry will be used to validate the DEMs.
2021-R23	University of Oxford	Pleiades Stereo	Huaxian, China	The 1556 earthquake is the most devastating earthquake known, but its source is poorly characterized. The region is one of the most densely populated in China, with the city of Xian having a population of 8 million, and with widespread urbanization. Characterisation of active faults, past earthquakes, and their effects help in mitigation of future disasters	The order enabled us to cover the entire length of the ruptures from the 1556 earthquake in Xian, China.

Results with SAR - Examples

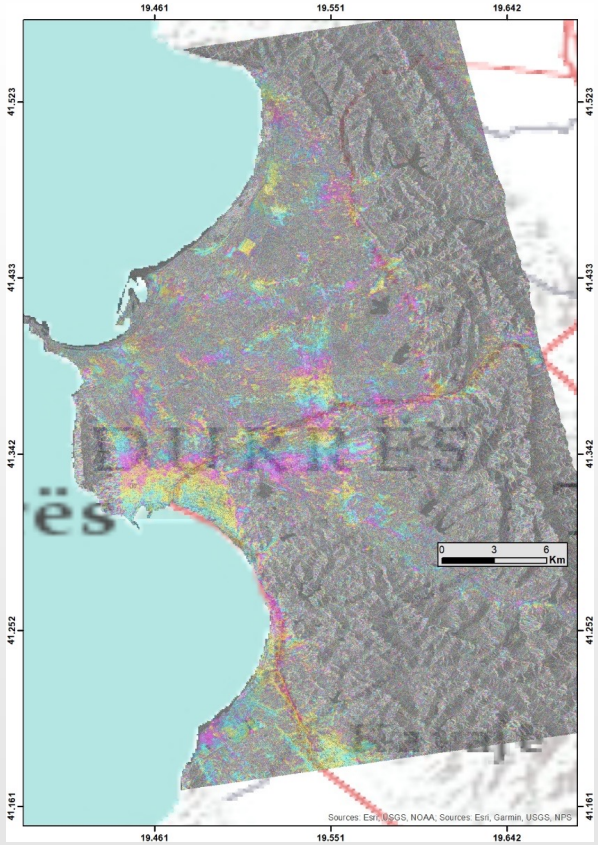
2021-R19



Contains modified Copernicus Sentinel-1 data (2015-2020), processed by AUTh

Composite map of decorrelated areas. Regions suffered extended liquefactions collocate with riverbeds. Contains Copernicus Sentinel-1 modified data.

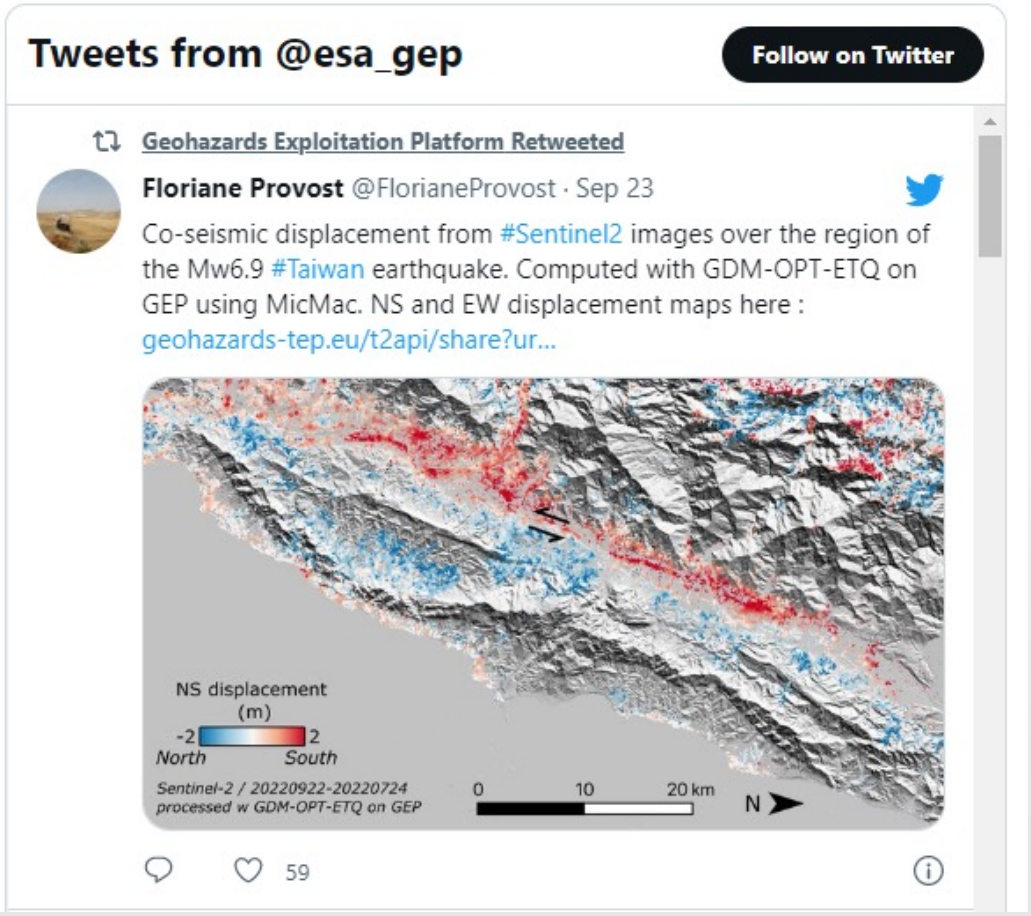
2019-R11



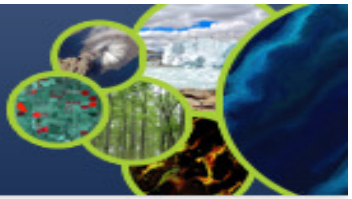
Coseismic fringes was retrieved on Coseismic CSK pair (ascending orbit) In Durres, Albania

Additional Example

Example of a deformation product using Sentinel-2 that could be generated automatically



Promotion and Publications



Papers, Presentations, Posters:

- **Published** Papers

E., Elliott, J. R., Silva, V., Vilar-Vega, M., and Kane, D.: **Contrasting seismic risk for Santiago, Chile, from near-field and distant earthquake sources**, Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2019-30

Amey, R. M. J., J. R. Elliott, E. Hussain, R. J. Walker, M. Pagani, V. Silva, K. Abdrakhmatov & C. S. Watson (2021), **Significant seismic risk potential from buried faults beneath Almaty city, Kazakhstan, revealed from high resolution satellite DEMs**, Earth & Space Science, 8, https://doi:10.1029/2021EA001664 .

Watson, C. S., Elliott, J. R., Ebmeier, S. K., Vásquez, M. A., Zapata, C., Bonilla-Bedoya, S., Cubillo, P., Orbe, D. F., Córdova, M., Menoscal, J., and Sevilla, E.: **Enhancing disaster risk resilience using greenspace in urbanising Quito, Ecuador**, Nat. Hazards Earth Syst. Sci., 22, 1699–1721, 2022. https://doi.org/10.5194/nhess-22-1699-2022 , May 2022.

- **Submitted or preprint** Papers

Watson, C. S. J., J. R. Elliott, R. M. J. Amey & K. Abdrakhmatov, **Multi-sensor 4D City Mapping for Updating Building Exposure to Inform Seismic Risk in Bishkek, Kyrgyzstan**, Journal of Selected Topics in Applied Earth Observations and Remote Sensing.

Ruth M.J. Amey, John R. Elliott, C. Scott Watson, Richard Walker, Marco Pagani, Vitor Silva, Ekbal Hussain, Kanatbek E. Abdrakhmatov, Sultan Baikulov, Gulkaiyr tilek Kyzy, **Improving urban seismic risk estimates for Bishkek, Kyrgyzstan incorporating recent geological knowledge of hazards**, Nat. Hazards, EarthArXiv https://doi.org/10.31223/X5KG9X

Promotion and Publications

➢ Web pages

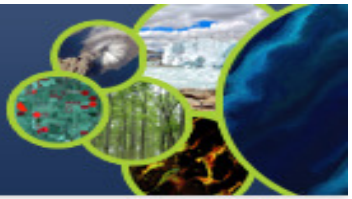
http://www.esa.int/spaceinimages/Images/2018/10/Fault_line_land_movement_in_Indonesia

http://www.esa.int/spaceinimages/Images/2018/10/Indonesia_earthquake_displacement_map

https://discuss.terradue.com/t/earthquake-hits-greece-and-turkey/950

https://eo4society.esa.int/2019/07/30/mapping-the-faults-of-2019-california-earthquakes-with-sentinel-1-2

Promotion and Publications



Conferences:

Watson, S., Elliot, J., Ebmeier, S.K., Vásquez, M.A., Zapata, C., Bonilla-Bedoya, S., Cubillo, P., Orbe, D.F., Córdova, M., Menoscal, J., Sevilla, E.: Enhancing disaster risk resilience using greenspace in urbanising Quito, Ecuador, Poster, Living Planet Symposium 2022.

Marshall, N., Walker, R., Ou1, Q. and Gruetzner, C.: A re-evaluation of the 5th October 1948 M7.3 Ashgabat earthquake, EGU22-10062, https://doi.org/10.5194/egusphere-egu22-10066

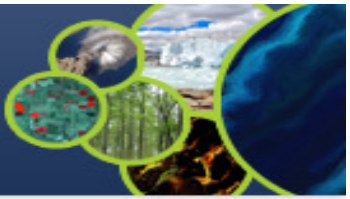
Johnson, B., Kulikova, G., Bergman, E., Krueger, F., Pierce, I., Hollingsworth, J., Copley, A., Kendall, M., Walker, R.:Source parameters and locations of the 1949 Mw7. 4 Khait and 1907 Mw7. 6 Karatag earthquakes: implications for how mountain ranges collide, EGU22-12020, https://doi.org/10.5194/egusphere-egu22-12020

Amey, R., Elliott, J.R., Watson, C.S., Walker, R.T., Hussain, E., Pagani, M., Silva, V., Abdrakhmatov, K., Baikulov, S., Kyzy, G.T.: Using satellite-derived digital elevation models to better inform seismic hazard and risk models for Almaty and Bishkek in the Tien Shan, Central Asia, AGU Fall Meeting 2021, https://agu.confex.com/agu/fm21/meetingapp.cgi/Paper/938531

Wilkinson, R., Daout, S., Parsons, B., Walker, R.T., A time-series InSAR study of faulting and folding in the Tajik Basin, AGU Fall Meeting 2020, 2020AGUFMG021.0007W https://ui.adsabs.harvard.edu/abs/2020AGUFMG021.0007W/abstract

Elias, P., Ganas, A., Briole, P., Valkaniotis, S., Escartin, J., Tsironi, V., Karasante, I., and Kosma, C. 2021. Co-seismic deformation, field observations and seismic fault model of the Oct. 30, 2020 Mw=7.0 Samos earthquake, Aegean Sea, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-14595, https://doi.org/10.5194/egusphere-egu21-14595

Lessons Learned



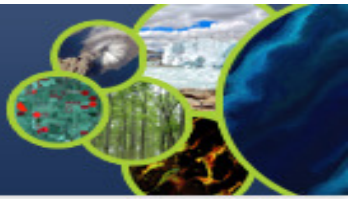
Data use

- The use of Pleiades data formed the basis for estimating 3D offsets associated with earthquakes (e.g. M7.4 earthquake in Qinghai, China). Pleiades data was essential in producing DEMs with far better resolutions than what could be accomplished with publicly available data.
- Automated Processing of S1 In-SAR is in place but was not put into production.
- The tri-stereo imagery from Pleiades has proven to be more successful for extracting buildings than from normal stereo which is a large advantage over other systems.

Recommendations for rapid generation and improved accuracy of results

- Automated production of products with In-SAR is ready to be put in production (sustainability issue).
- A multi-sensor InSAR coverage can strongly improve the accuracy of the ground deformation measurement. Optimally, at least one X-, C-, and L- interferogram should be used for each orbit direction. Ex. X- (TerraSAR), C- (RADARSAT) and L- (SAOCOM)
- Constraining the modeling with ground-based information (focal mechanisms, relocated seismicity, geological information, etc.) and jointly inverting the SAR results with other geodetic and seismic data (GPS displacements, strong motion data, broadband seismograms), largely improves the source detail. These are normally second order models, requiring several days to be generated.
- Access to newly developed 2m global DEM datasets (NASA Earth DEM) to give coverage over wider areas and complement the very small regions in which we have <1 m data
- Access to the new generation Pleiades Neo data would provide even better results when correcting or creating new DEMs.

Follow-up activities from Demonstrator partners



- **The University of Oxford** and **The Institute of Atmospheric Physics and Seismology,** Turkmenistan.

  They continue to work together to implement results from the demonstrator project. Close contact is held with the UK embassy in Turkmenistan to study the potential impact of the demonstration services.

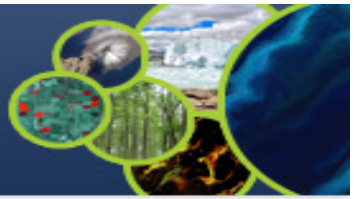
- **University of Leeds** and **The Municipality of Quito**

  Through the *Tomorrow's Cities* project supported by the demonstrator, products are integrated into disaster risk reduction for urban planning. Products are sill being generated using data from the demonstrator in the framework of the *Tomorrow's Cities* project.

- **John Elliot (University of Leeds)**

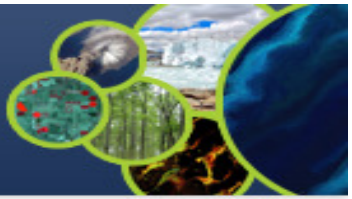
  States that he would like to be involved in another similar activity coordinated by CEOS and could continue the provision of staff time to derive value added products contributing to better interpretations for seismic hazard (with subsequent engagement with stakeholders responsible for seismic hazard assessments). If data was provided again in the future, the user base could expand through the UK umbrella group COMET (Centre for the observation and Modelling of Earthquakes, Volcanoes and Tectonics).

Application Development Possibilities



- Increase the timeliness of hazard and risk analysis by pursuing development and standardization of automated chains for generation and distribution of hazard maps and preliminary models.
- Provide EO data in a cost-effective way to achieve the objectives of the seismic hazards community (regional to global scale coverage).
- Focus on acceptance and adoption (transfer of skills) of EO services. Using cloud processing environments is especially important in regions with low quality internet and limited access to processing capabilities.
- Take into account new EO missions including the new space (new constellations with CubeSATs)
- The EO sector should further develop EO processing chains to support more EO missions for multi-thematic products (optical and radar).

Conclusion



The Demonstrator addressed the need for improvement of EO exploitation capacity in many high-risk countries. CEOS agencies have played a key role with their contributions to the Demonstrator.

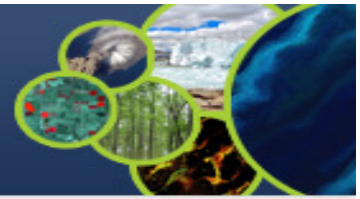
Deploying EO solutions in the future could be done by:

1.) Stimulating international collaboration (with stakeholders and users) however, this requires financing from non-space contributors (if benefit is higher than cost).

2.) The EO sector could contribute by providing affordable resources, either commercial EO products, or free or low-cost online services for EO data processing (such as the GEP initiated by ESA, OPERA run by NASA JPL, etc.)

- We propose to report feedback on the follow up activities by partners beyond the Demonstrator.

- Agenda item 15 will present new ideas from ESA for new activities under the CEOS WGD.



Thank you

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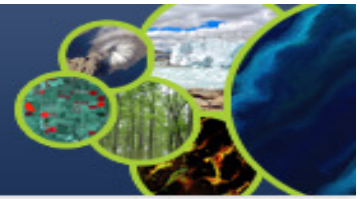
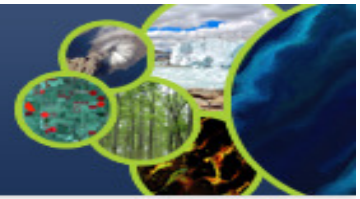




On-going studies with optical VHR imagery (1)

Quito, Ecuador), Nairobi (Kenya) and Kathmandu (Nepal), University of Leeds et al.

Tomorrow's Cities: **deriving models of multi-hazard risk to inform urban development planning** for four major capital cities using **Pleiades** VHR images

✓ ***In progress*** *(Quito and Kathmandu completed)*

Qinghai, China (University of Leeds, COMET et al.)

Deriving DEMs of the **2021 May 21st Mw 7.3 Maduo earthquake** rupture using **Pleiades tri-stereo** data to **map the fault rupture zone**. This will aid field teams in mapping out the rupture in the field, as well as create remotely derived datasets against which to compare this information to improve our understanding of earthquake faulting events.

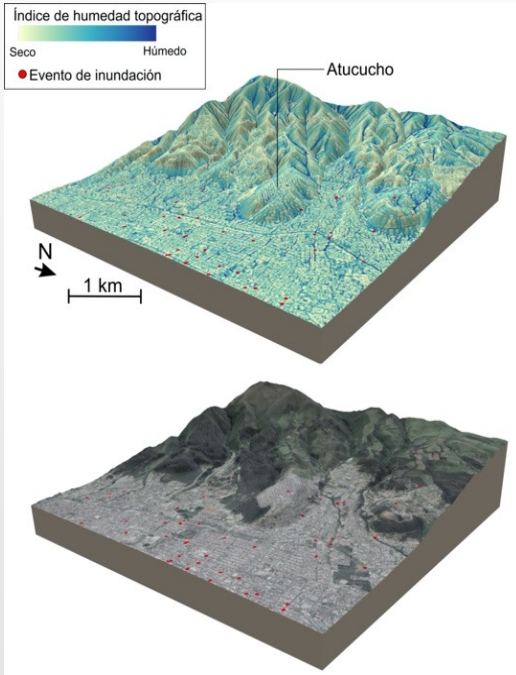
✓ ***In progress*** *(investigation of artefacts found)*

Shamakhi, Azerbaijan (University of Oxford et al.)

Using **Pleiades stereo** data to **support active fault characterisation and palaeoseismic trenching along the edge of the Caucasus mountains and within the Kura basin**, where rapid slip is expected, but evidence of active faulting is subtle.

project co-funded through a UKRI GCRF award

✓ ***In progress,*** *fieldwork has been postponed for late 2021 - early 2022.*



Wetness index used to show movement of water around and into the city of Quito, generated using Pleiades data

On-going studies with optical VHR imagery (2)

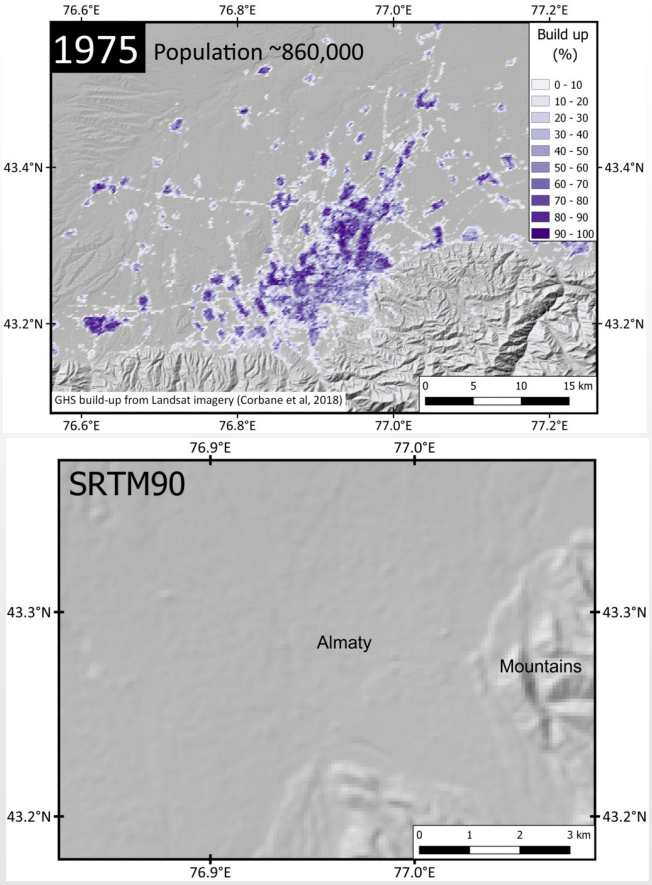
Almaty, Kazakhstan (University of Oxford, University of Leeds, COMET, BGS, GEM Foundation et al.)

Active faulting using **Pleiades stereo** data to identify and characterise active fault scarps in urban regions along the Zailisky rangefront in Kazakhstan, including the city of Almaty (2M population) and various other large towns (including Bishkek, Kyrgyzstan).

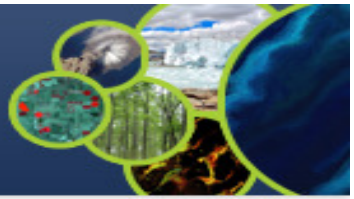
- ✓ ***In progress**, DEM analysis combined with a successful palaeo-seismic survey, suggested occasional large earthquakes over the last 10,000 years. (project completion foreseen Q2 2022, results to support further detailed work and interactions with policy makers)*

Dushanbe, Tajikistan (University of Oxford)

- ✓ ***In progress** (presentation follows)*



On-going studies with optical VHR imagery (3)



Ashgabat, Turkmenistan (University of Oxford):

Examine the landscape for signs of **faulting within urban Ashgabat associated with the destructive 1948 earthquake**, and to undertake reconnaissance in support of further palaeo-seismic trenching studies.

- ✓ ***Ongoing with the analysis****, completion of the 1948 study foreseen in summer 2022. Fieldwork in Turkmenistan is postponed (for 2023).*

Pamir, Tajikistan (University of Oxford):

Undertake **pilot investigations of earthquake rupture associated with the destructive 1911 and 1949 earthquakes at Sarez and Khait** and investigate **past earthquake behaviour on the major Darwaz fault**, for which no historical earthquakes are reported. This project consists of three small polygons of stereo Pleiades data.

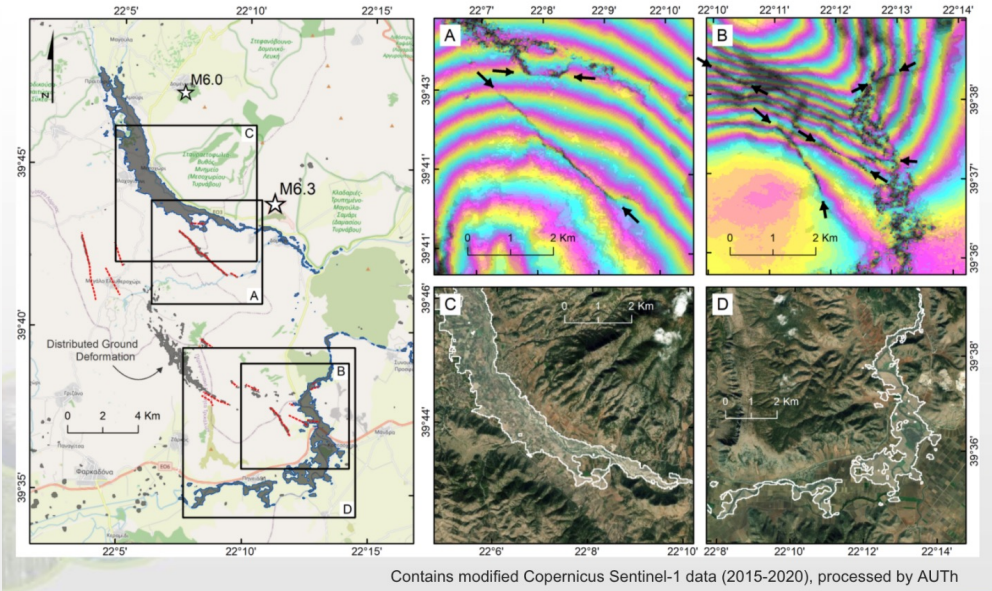
- ✓ *Khait polygon is **progressing well**, completion foreseen by the end of 2021. 30 cm Worldview-3 data used to provide additional details of some subtle features.*
- ✓ *Sarez and Darwaz is currently **on hold** (unable to organise the field components of the work, postponed for 2022).*

On-going studies with SAR

Thessaly, Greece (INGV and AUTH)

INGV and AUTH started collaboration on joint analysis processing **Sentinel-1 and CosmoSkyMed for the Thessaly M6.3 in March 2021** for post seismic relaxation of the area. GEP services are also used.

✓ ***In progress*** *(further details under the Geohazards Lab presentation)*



Contains modified Copernicus Sentinel-1 data (2015-2020), processed by AUTh

Composite map of decorrelated areas. Regions suffered extended liquefactions collocate with riverbeds. Contains Copernicus Sentinel-1 modified data.

Tehran, Iran (University of Tehran)

Mapping interseismic strain accumulation over the urban area of Tehran.

✓ *Approved, awaiting feedback*

Promotion and publications

Examples of processed satellite EO products

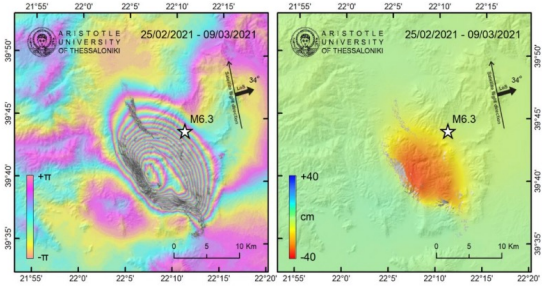


Figure 8. Example of co-seismic differential interferogram (left image) using Copernicus Sentinel-1 pre-event (25/02/2021) and post-event (09/03/2021) data, corresponding to the ground motion map (right image) of the Tirnavos (Greece) M6.3 earthquake on 03/03/2021. The ground motion map shows a maximum displacement at ~38cm. No rupture reached the surface. Contains modified Copernicus Sentinel data (2021), processed by Aristotle University of Thessaloniki (AUTh).

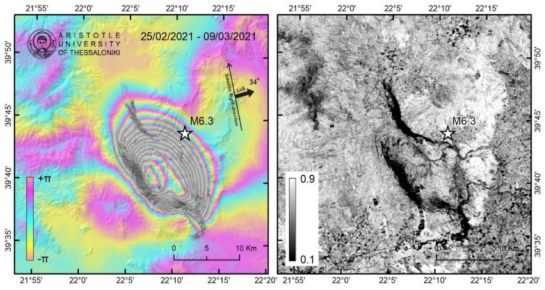


Figure 9. Example of co-seismic differential interferogram (left image) and interferometric coherence map (right image) of the M6.3 earthquake in Tirnavos (Greece), using Copernicus Sentinel-1 pre-event (25/02/2021) and post-event (09/03/2021) data. Wide-spread liquefactions along river basins and distributed surface deformation are depicted by patterns of low coherence (areas in black) nearby the epicentral area. Contains modified Copernicus Sentinel data (2021), processed online on the Geohazards Exploitation Platform (GEP) by Aristotle University of Thessaloniki (AUTh).

Papers, Presentations, Posters:

- Paper **to be submitted**

Improving urban risk estimates for Bishkek, Kyrgyzstan, from improved geological knowledge of hazards (Ruth M.J. Amey, John R. Elliott, C. Scott Watson, Richard Walker, Marco Pagani, Vitor Silva, Ekbal Hussain, Kanatbek E. Abdrakhmatov, Sultan Baikulov, Gulkaiyr tilek Kyzy)

- **Paper published (American Geophysical Journal)**

Significant Seismic Risk Potential from Buried Faults Beneath Almaty City, Kazakhstan, revealed from high-resolution satellite DEMs (Ruth M.J. Amey, John R. Elliott, Ekbal Hussain, Richard Walker, MarcoPagani, Vitor Silva, Kanatbek E. Abdrakhmatov, C. Scott Watson)

Web page, articles and Twitter:

- Seismic Demonstrator web page updated
- Several tweets published