Centre of EO Research & Satellite Remote Sensing

Υπηρεσίες διαχείρισης μεγάλου όγκου δορυφορικών δεδομένων για την παρακολούθηση, αντιμετώπιση και πρόβλεψη γεωκινδύνων

Geohazards

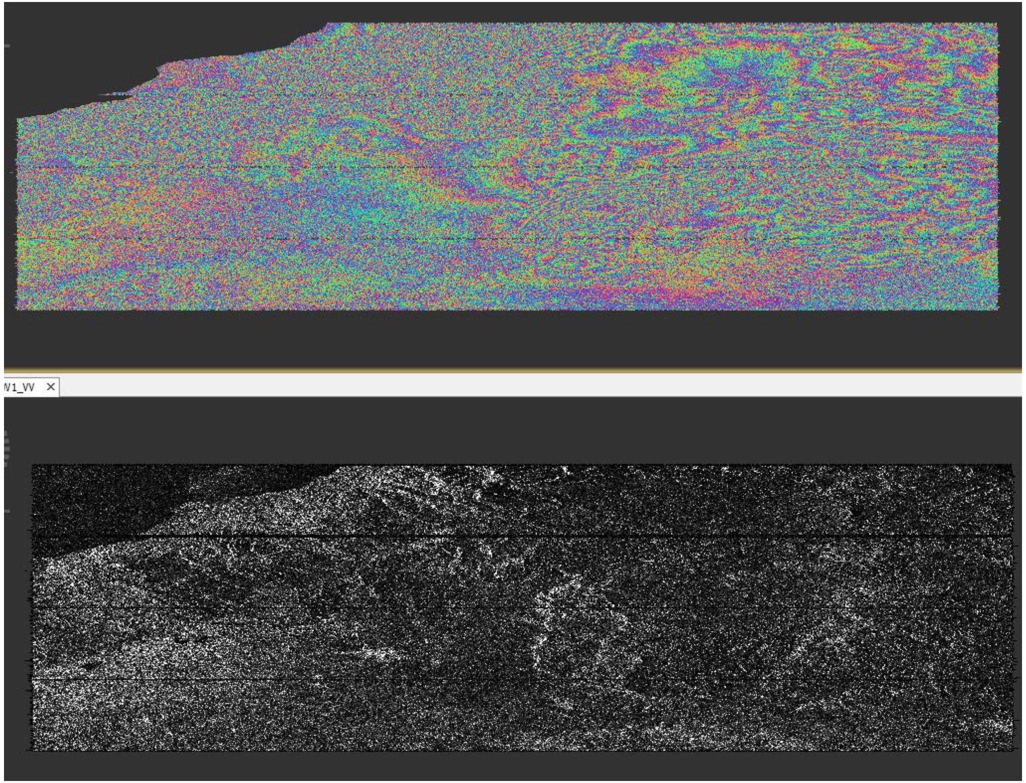
InSAR and PSI applications

- Monitor tectonic activities
- Subsidence associated to rapid urbanization
- Subsidence associated to groundwater and gas extraction
- Subsidence associated to subway construction and operation
- Monitor ground deformation

- Building deformation related to landslides
- Volcanic deformation
- Deformation associated to mining activities
- Natural and anthropogenic coastal deformation

Phase and amplitude

Thessaly plain



Phase

Amplitude

SAR Interferometry

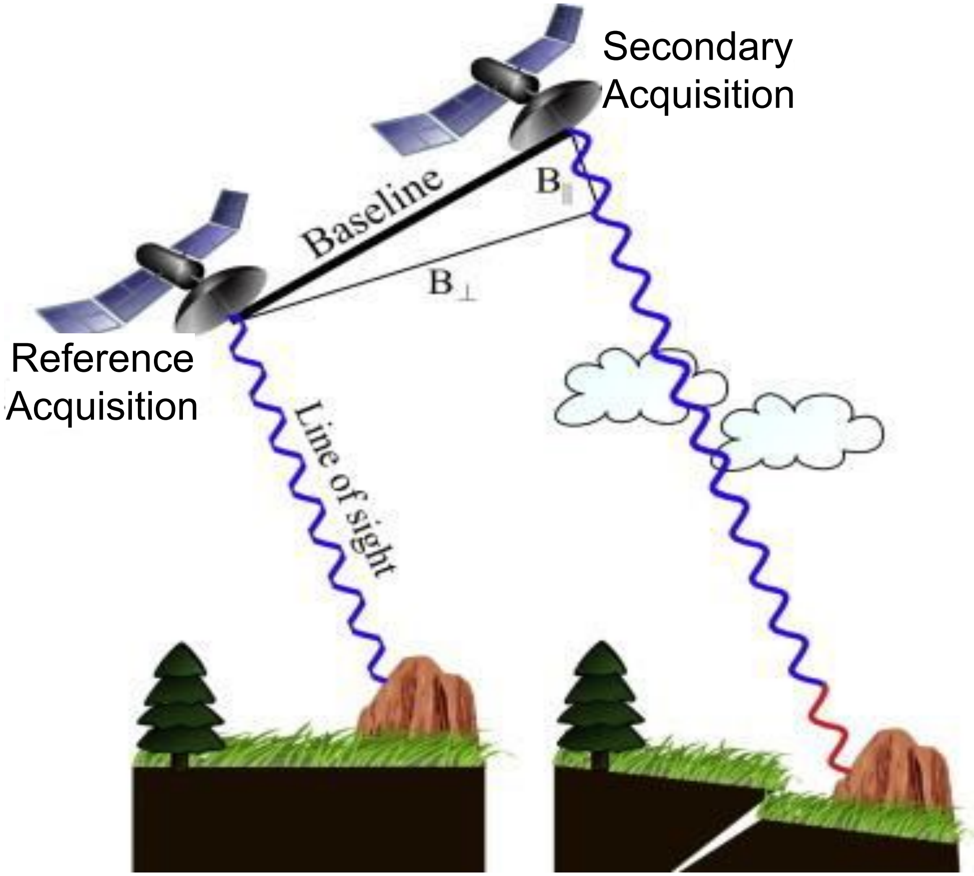
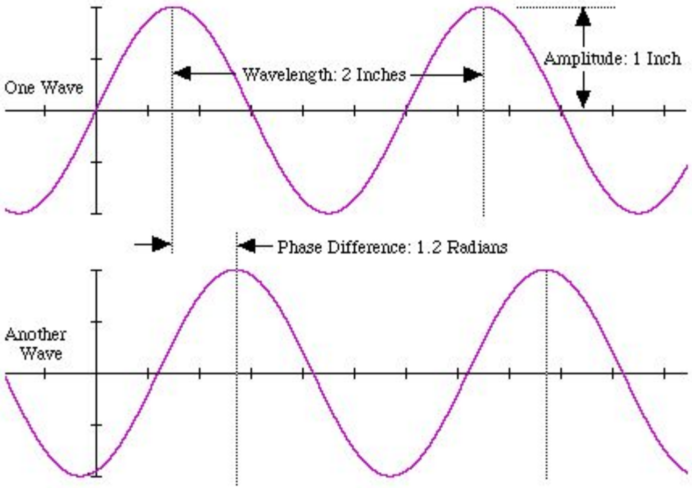


Image from: Batuhan Osmanoğlu et al,2016



$$\phi_1 = -\frac{4\pi}{\lambda} R + \phi_{scatt,1}$$

$$\phi_2 = -\frac{4\pi}{\lambda} (R + \Delta R) + \phi_{scatt,2}$$

$$\phi = \phi_1 - \phi_2 = \frac{4\pi}{\lambda} \Delta R$$

The principal of SAR interferometry technique, lies on the measurement of the phase difference between two or more SAR images, acquired from different look-angles and times.

Phase components

$$\Delta\varphi = \Delta\varphi_{flat} + \Delta\varphi_{elevation} + \Delta\varphi_{displacement} + \Delta\varphi_{atmosphere} + \Delta\varphi_{noise}$$

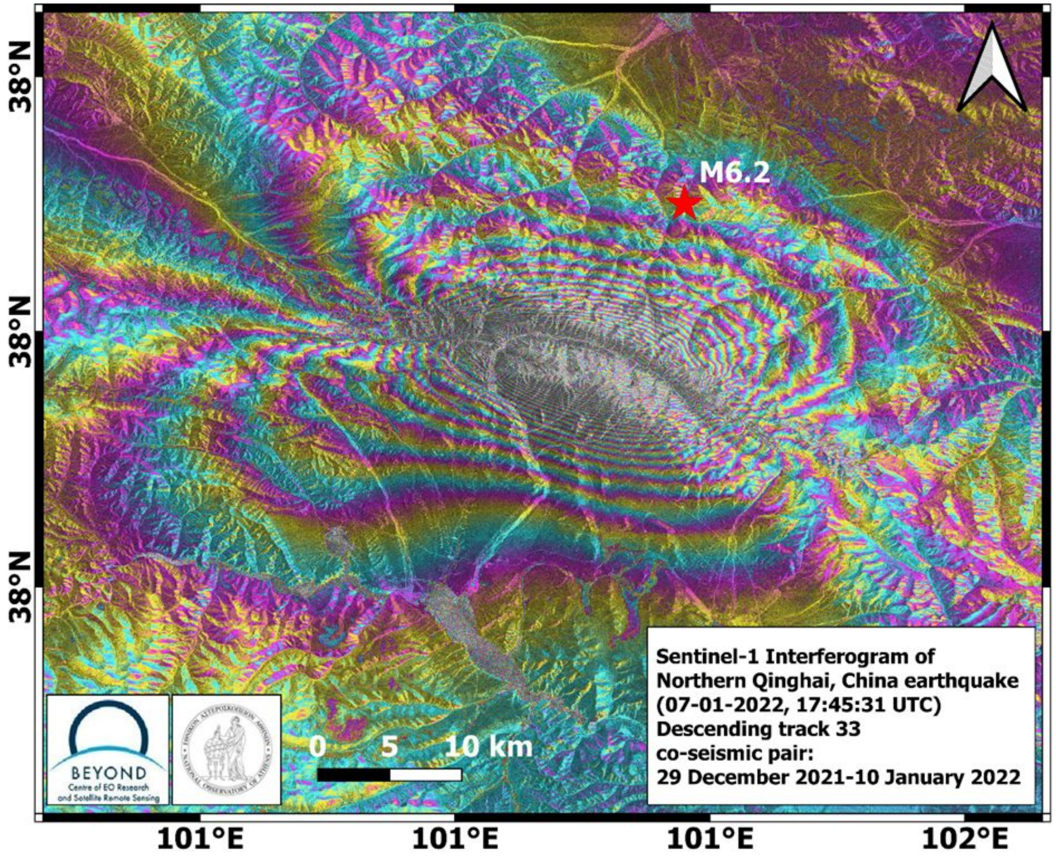
$$\Delta\varphi_{flat} = -\frac{4\pi}{\lambda}\frac{B_n s}{R\tan\theta}$$

$$\Delta\varphi_{elevation} = -\frac{\Delta q}{\sin\theta}\cdot\frac{B_n}{R_0}\cdot\frac{4\pi}{\lambda}$$

$$\Delta\varphi_{displacement} = +\frac{4\pi}{\lambda}d$$

Source: Luis Veci, ESA, TOPS Interferometry Tutorial

Interferogram



Source: geObservatory (http://geobservatory.beyond-eocenter.eu/)

geObservatory

http://geobservatory.beyond-eocenter.eu/

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Most relevant

Ioannis Kotsis • 2nd · 1y
Senior Surveyor Engineer at AKTOR SA
Less than 24hrs after!!! Congratulations. I remember the good old ERS and Envisat days we had to wait almost a month for the precise orbits to begin the processing...
Like · 1 | Reply

gary Hinkley • 2nd · 1y
Principal Owner
A further opportunity to understand Satellite / Remote Sensing , I sincerely appreciate & thank BEYOND ! Gary H .
Like · 1 | Reply

geObservatory
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geObservatory

Events

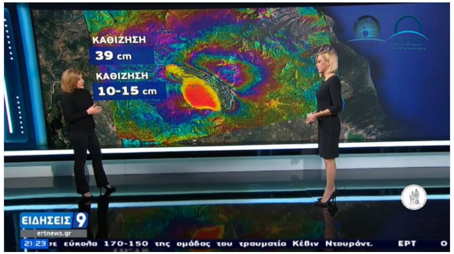
Code	Location	Magn...	Depth	Date/...	Lat	Lng
	filter column...					
96	EASTERN XIZANG	5.7	5	2021-03-1...	31.91	92.96
95	GREECE	5.6	7	2021-03-1...	39.84	22.01
93	GREECE	5.8	10	2021-03-0...	39.78	22.12

Interferograms

View	Type	Master	Slave	Orbit	Mode	Opacity	Download
☐	co-seismic	2021-02-25 16:24:15	2021-03-03 16:23:34	102	ASCENDING		
☐	pre-seismic	2021-02-25 16:24:15	2021-02-19 16:23:34	102	ASCENDING		

Beyond EO Center
9 Μαρτίου 2021 ·

Με την πρώτη διαθέσιμη δορυφορική εικόνα SAR στις 8 Μαρτίου 2021, υψηλής ανάλυσης, που συλλέχτηκε από το Hellenic Mirror Site, το geObservatory παρήγαγε τη χαρτογράφηση της εδαφικής παραμόρφωσης που είναι το αποτέλεσμα των δύο σεισμών μαζί, στην ευρύτερη πληγείσα περιοχή. Η χαρτογραφηθείσα συνολική εδαφική παραμόρφωση και από τα δύο σεισμικά γεγονότα, σύμφωνα με τη νέα πρώτη εκτίμηση, όπως φαίνεται στο συμβολόγραμμα και τον χάρτη παραμόρφωσης δείχνει να επεκτείνεται στα ΒΔ προς τα χωριά Βερδικούσα και Δομένικο, καθώς επίσης και ΝΑ προς τα χωριά Κουτσόχερο, Μάνδρα, Αμυγδαλιά με μέγεθος παραμόρφωσης της τάξης των 10-15εκ.
Η συγκεκριμένη υπηρεσία παρουσιάστηκε χτες από την @ΕΡΤ Α.Ε.
Beyond EO Center Εθνικόν Αστεροσκοπείον Αθηνών Ινστιτούτο Αστρονομίας, Αστροφυσικής, Διαστημικών Εφαρμογών,Τηλεπισκόπησης



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Masih Shahhosseini • 2nd · 1y
Surveying & Mechanical Engineer Verme...
Thanks for posting
Like | Reply

Reda Meftahi • 3rd+ · 1y
Co-founder & Director Survey Intelligence
Very interesting to see the difference between the ascending and descending images clearly indicating a strong horizontal component of the displacement.
Like | Reply

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Dimitrios Michelakis, PhD • 2nd · 1y
Global Head of Product
Thanks BEYOND CENTRE OF EO RESEARCH! Always interested to look at satellite derived information, especially when they are so beautiful! Does your centre have some type of service ...see more
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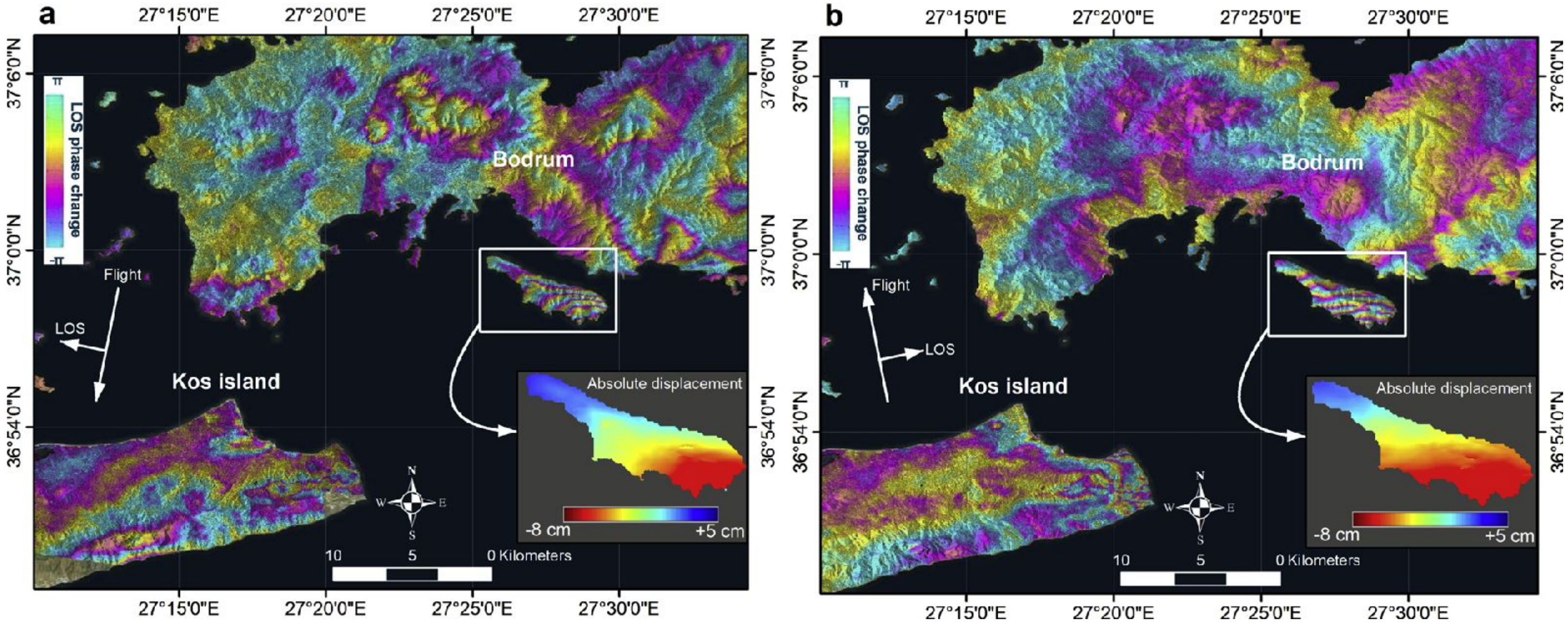
SENTINELS GREEK HUB

- Fully automated activation and interferogram generation for all major seismic events (M>5.5)
- Open access to all interferometric products
- 161 events ,1718 sentinel-1 images, 1396 interferograms
- Images are downloaded within 3 minutes from Greek Sentinel hubs

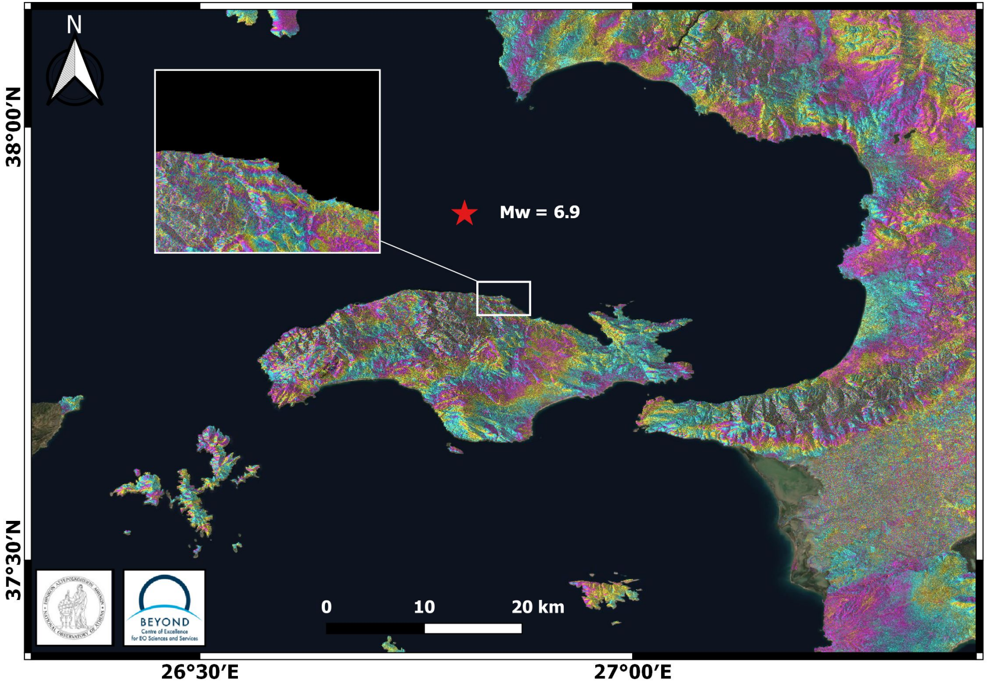
API Hub

Bodrum–Kos tsunamigenic earthquake (Mw6.6), July 2017



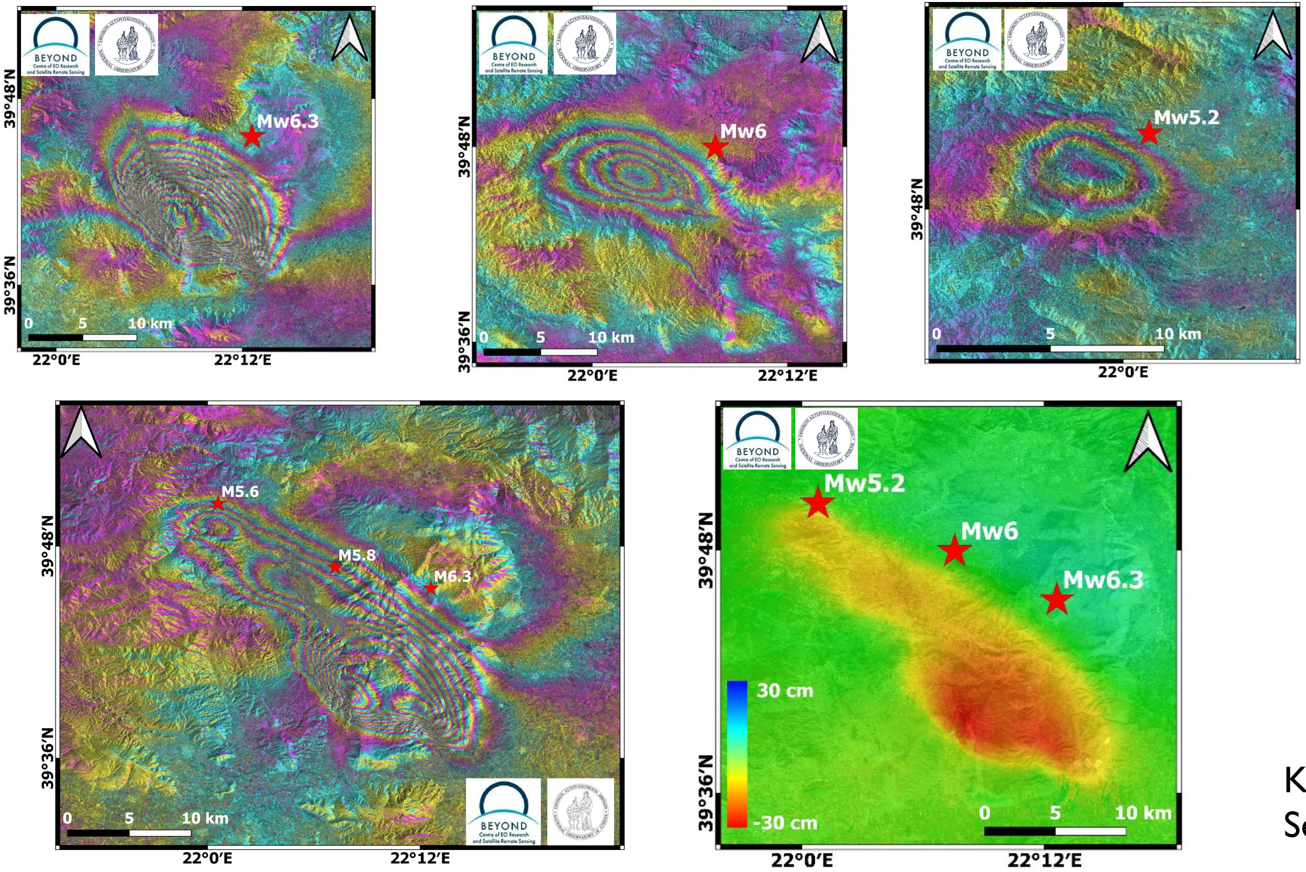
Papadopoulos et al., 2019 (doi: 10.1016/j.jog.2019.101646)

Samos M6.9 earthquake, October 2020



Contribution in the 248th newsletter of the Hellenic Association of Surveying engineers (P.S.D.A.T.M.)

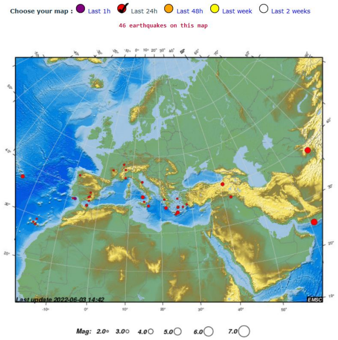
March 2021 Thessaly, Greece, earthquake sequence



Kontoes et al., June 2022, Seismol. Res. Lett.

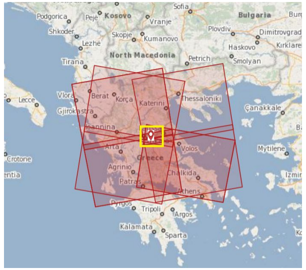
Geobservatory fully automatic service workflow in brief

Continuous retrieval of earthquake events using EMSC, USGS APIs



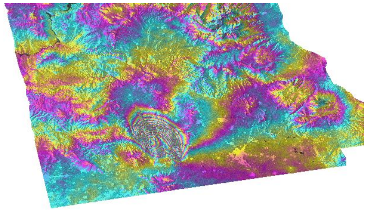
Automatic (or manual) activation of event processing (according magnitude, depth, location)

Automatic selection of Sentinel-1 SAR image pairs (reference, secondary) around epicenter for all passing orbits (ascending, descending) for the pre-seismic and co-seismic products

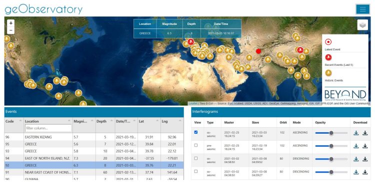


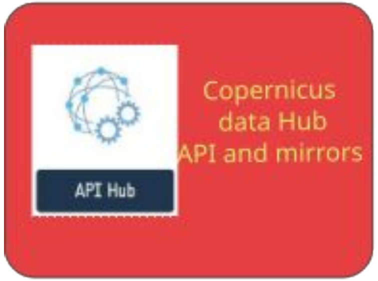
Continuously predict and check for availability and download images from the faster download location.

Execute workflow to produce products (interferogram, displacement etc.) for each master slave pair via parallel processing



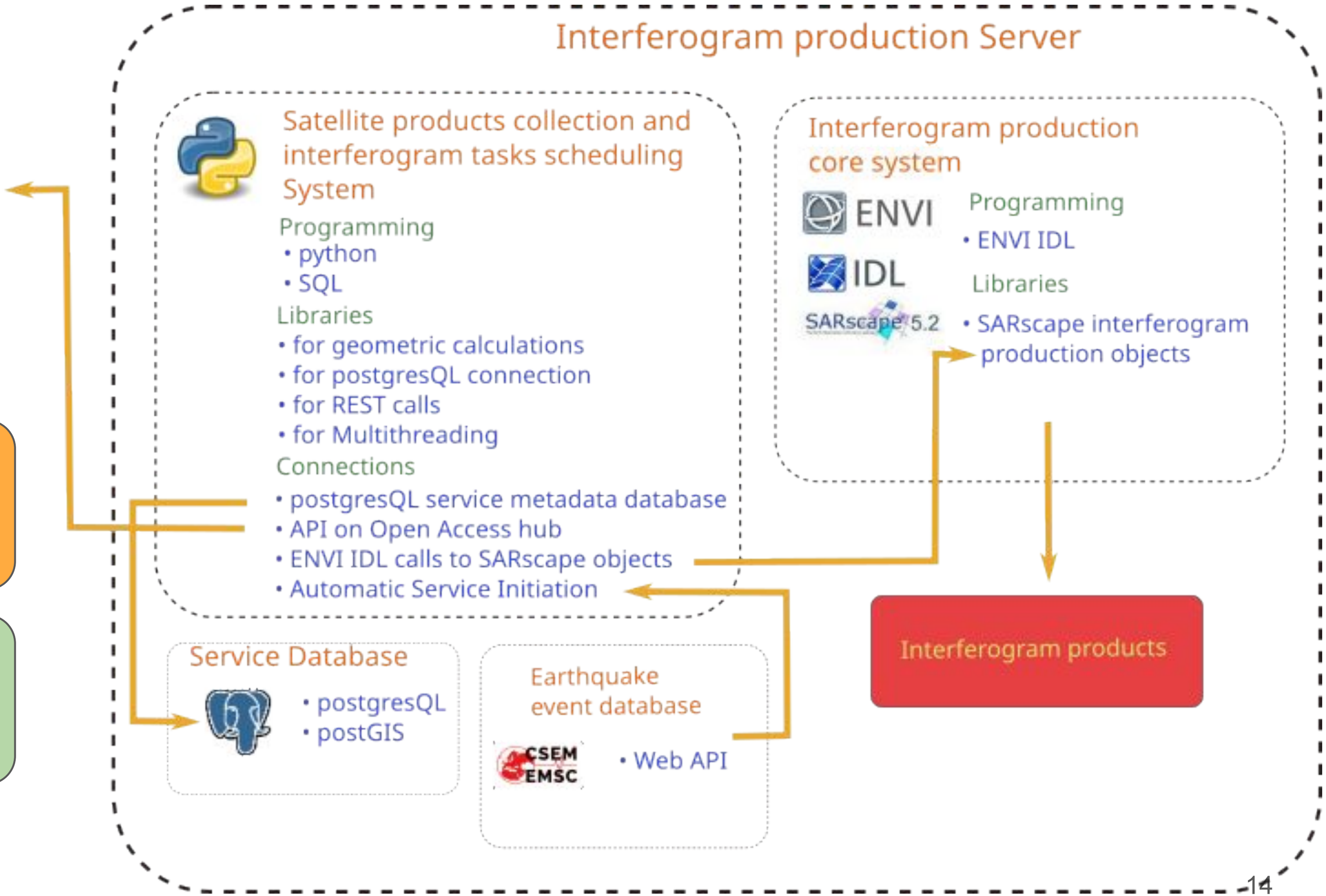
Upload to the user front-end the new products and update events





Workflow supports parallel task execution

Fully customizable and framework agnostic workflow engine

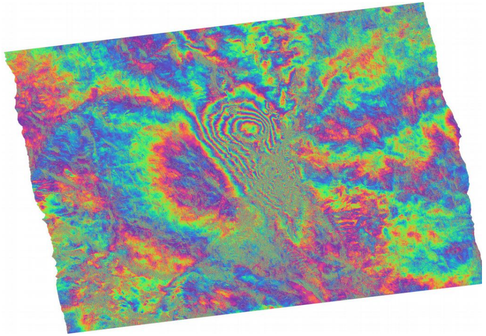


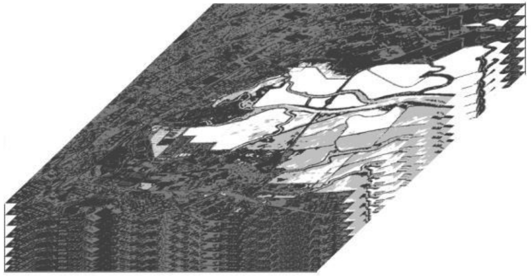
Future Work

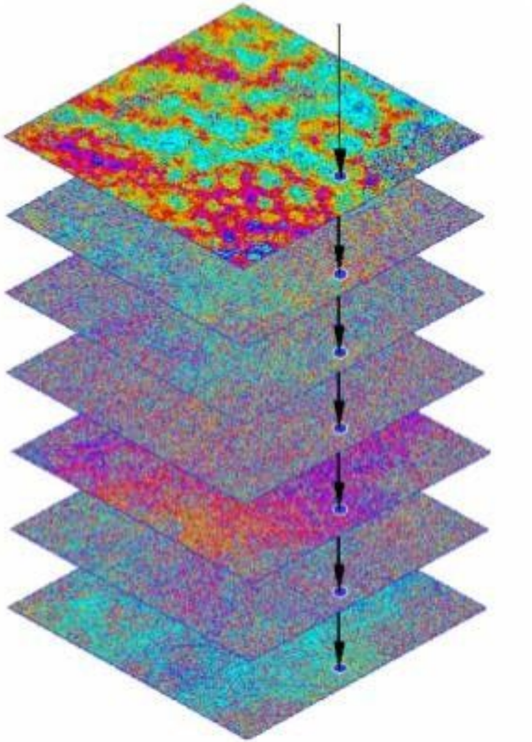
Geobservatory

- migrating to open source
- displacement maps
- other DInSAR related products

From DInSAR to multi-temporal SAR interferometry





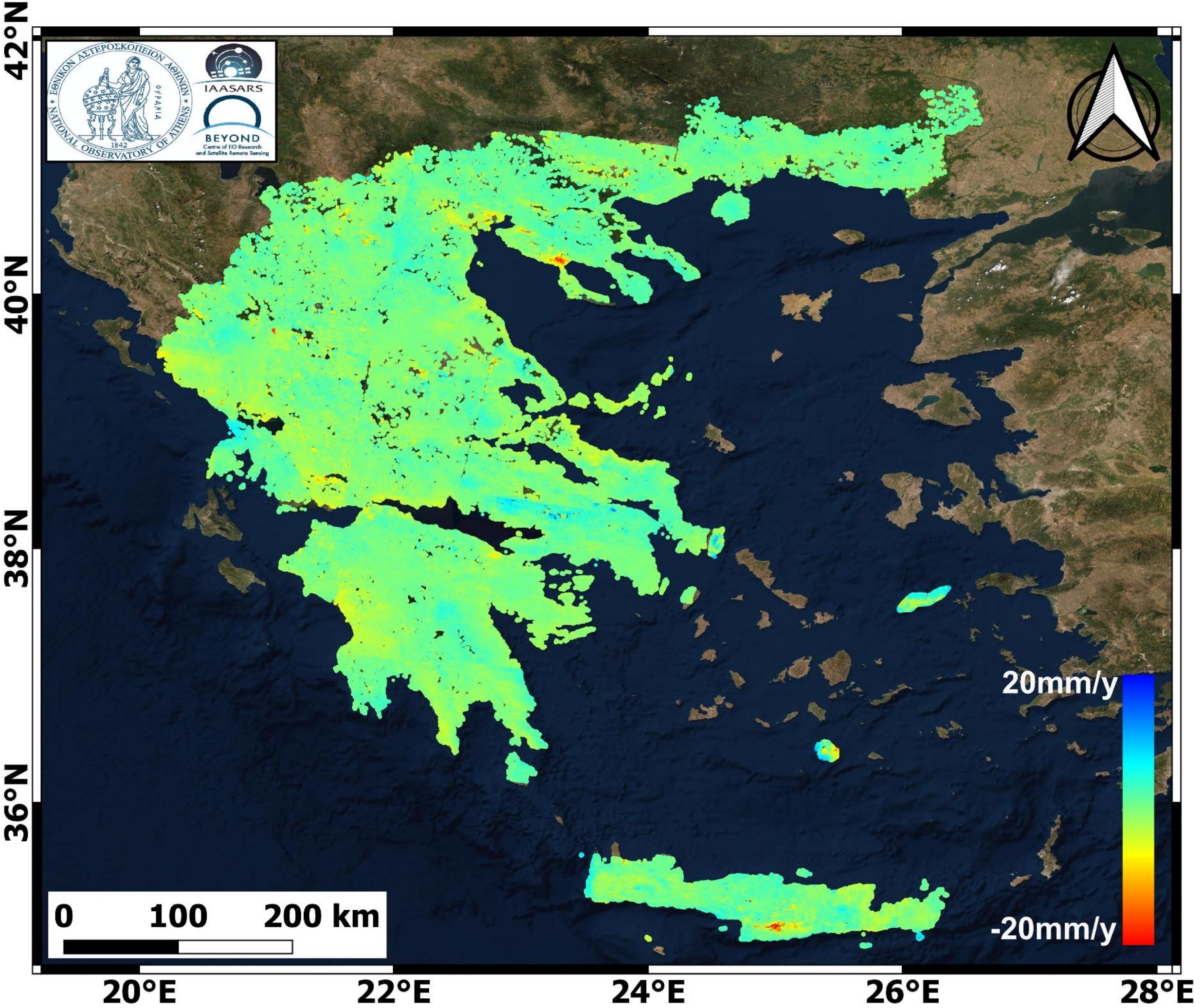


Big interferometric data processing

- P-SBAS (Casu et al, 2014)
- LiCSBAS (Morishita et al, 2020)
- InSAR Norway (https://insar.ngu.no/)
- BodenBewegungsdienst Deutschland (BBD) (https://bodenbewegungsdienst.bgr.de/)
- TRE ALTAMIRA and Geomatic Ventures Limited (GVL) (https://mangomap.com/geomatic-ventures-limited/maps/72883/united-kingdom-relative-deformation-map)
- Danish nationwide deformation monitoring (Bischo et al, 2020)
- InSAR Greece (Papoutsis et al, 2020)

InSAR Greece

14 frames
1.164 Sentinel-1 SLC images
110,496 km2
13.660.887 permanent scatterers

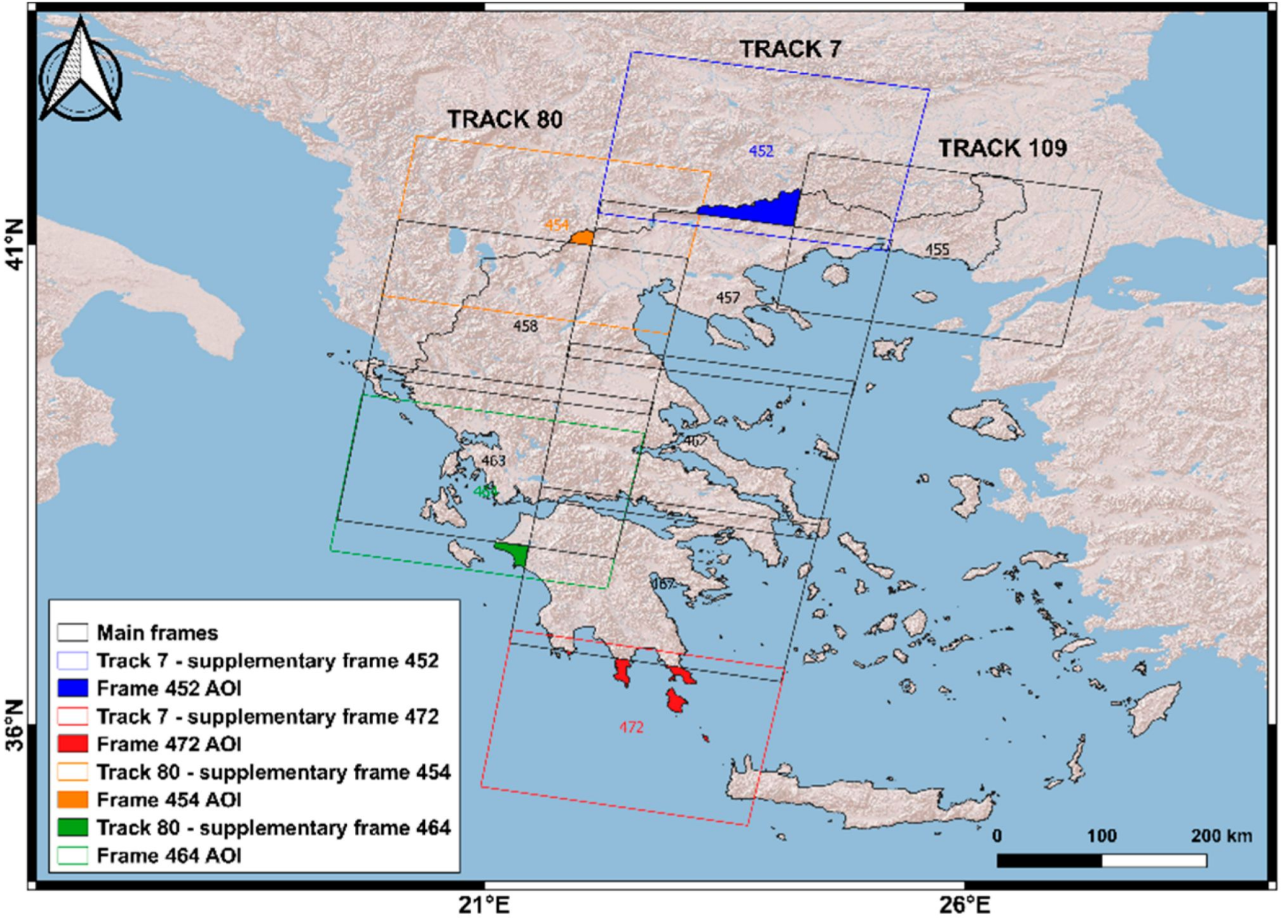


DESFA
Hellenic Gas Transmission System Operator S.A.

ΔΕΗ

ΕΘΝ. ΜΕΤΣΟΒ. ΠΟΛΥΤΕΧΝΕΙΟΝ
ΠΡΟΜΗΘΕΥΣ ΠΥΡΦΟΡΟΣ

Frames



TRACK 7
TRACK 80
TRACK 109
452
454
455
457
458
463
467
472
41°N
36°N
21°E
26°E
0
100
200 km
Main frames
Track 7 - supplementary frame 452
Frame 452 AOI
Track 7 - supplementary frame 472
Frame 472 AOI
Track 80 - supplementary frame 454
Frame 454 AOI
Track 80 - supplementary frame 464
Frame 464 AOI

Processing statistics

171 SLCs (3 SLC/month) → **9 TB (storage)** → **15 days/ frame (non parallelized)**

120 SLCs (2 SLC/month) → **6 TB (storage)** → **10 days/ frame (non parallelized)**

More than 3 TB of input SLC

Including the volume of intermediate products needed to reproduce all products resulted in a total storage size of ***12 TB****.*

- The InSAR Greece product was generated in 1.5 months
- For a full Sentinel-1 frame stack, data downloading ranges from 6 to 10 hours for a stack of 100 images
- However, these values are not absolute and many factors affect the processing time, e.g., the land cover of each frame.
- This time frame to map the entire country highlights the efficiency of our P-PSI processing chain.

Final corrections in PS displacements

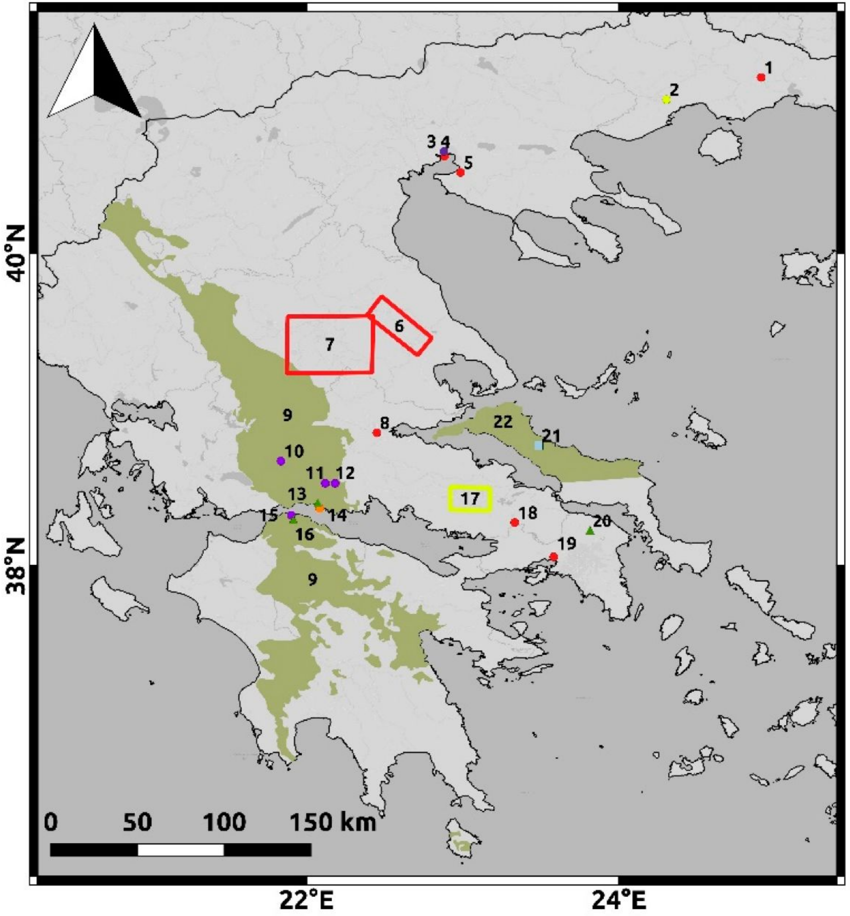
- Algorithm for non uniform split of a frame depending on land use land cover

- Several hours of additional manual analysis by an InSAR expert for resolving phase discontinuities

- Atmospheric phase noise correction

- A transformation of PSs from overlapping frames, by solving the inconsistencies of pixels belonging to adjacent tracks

InSAR Greece deformation phenomena



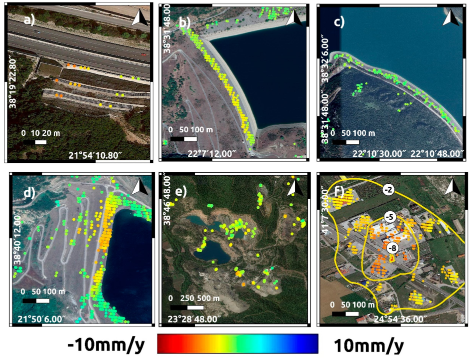
1. Xanthi industrial zone
2. Philippi plain
3. Kalochori-Sindos region (subsidence)
4. Kalochori-Sindos region (uplift)
5. Anthemountas basin
6. Eastern Thessaly plain
7. Western Thessaly plain
8. Spercheios basin
9. Pindos geotectonic zone
10. Evinos dam
11. Mornos dam
12. Mornos sealed bank
13. Sergoula landslide
14. Sergoula alluvial fun
15. Retaining system on A8
16. Panagopoula landslide
17. Kopaida plane
18. Theves industrial area
19. Thriasio plane
20. Malakasa landslide
21. Mantoudi magnesite mine
22. Northern Euboia Isl.

Identified deformation

- Land subsidence (overexploitation of the aquifers)
- Uplift (recharge of the aquifers)
- Land subsidence (natural compaction)
- Mining-induced deformation
- Landslides
- High landslide susceptibility zones
- Deforming constructions
- Land subsidence (organic soils oxidation)

InSAR Greece deformation phenomena

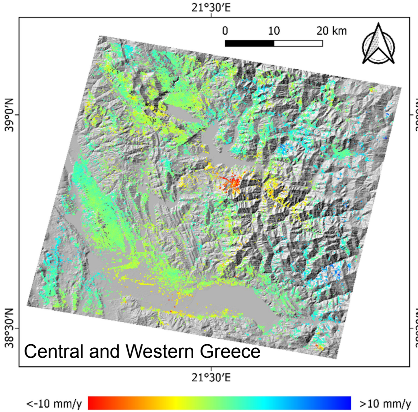
Deformation in construction sites



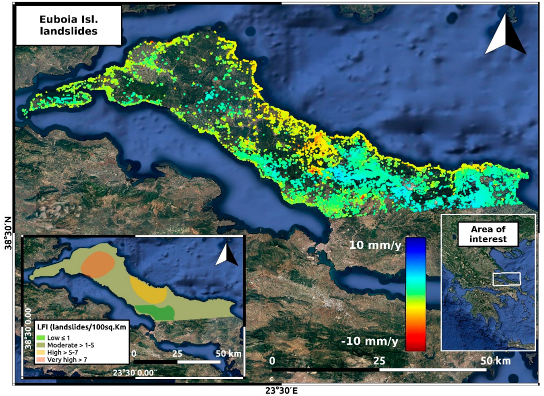
(a) Large retaining system (national road axis A8)
(b) Mornos dam body
(c) Sealed bank at the reservoir of the Mornos dam
(d) Evinos Earth dam body
(e) Abandoned Magnesite mine of Mantoudi
(f) Deforming site in the Xanthi industrial zone.

Papoutsis et al., 2020 (doi:10.3390/rs12193207)

Landslides

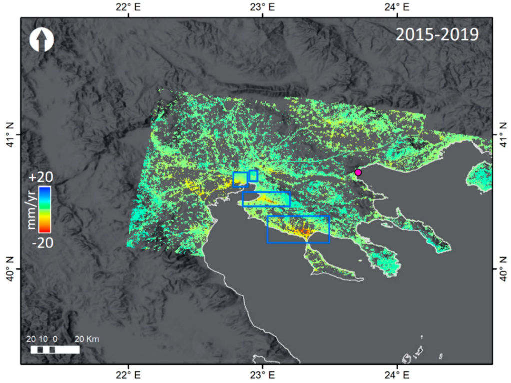


Kontoes et al, 2021 (doi:10.3390/land10040402)

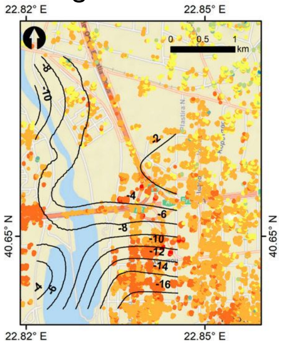


Papoutsis et al., 2020 (doi:10.3390/rs12193207)

Ground water overexploitation

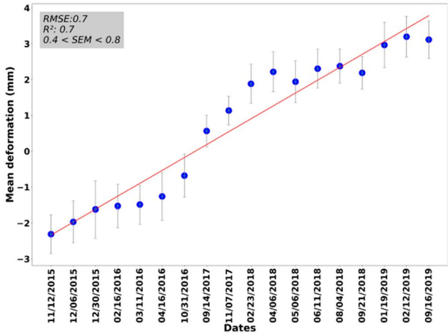


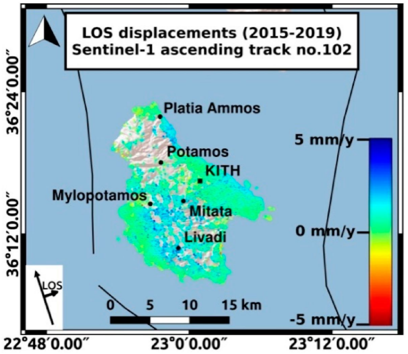
Underground water level changes in Kalochori



Svigkas et al., 2020(doi:10.3390/rs12152396)

Tectonic activity





After slip effects of 2006 Kythira earthquake

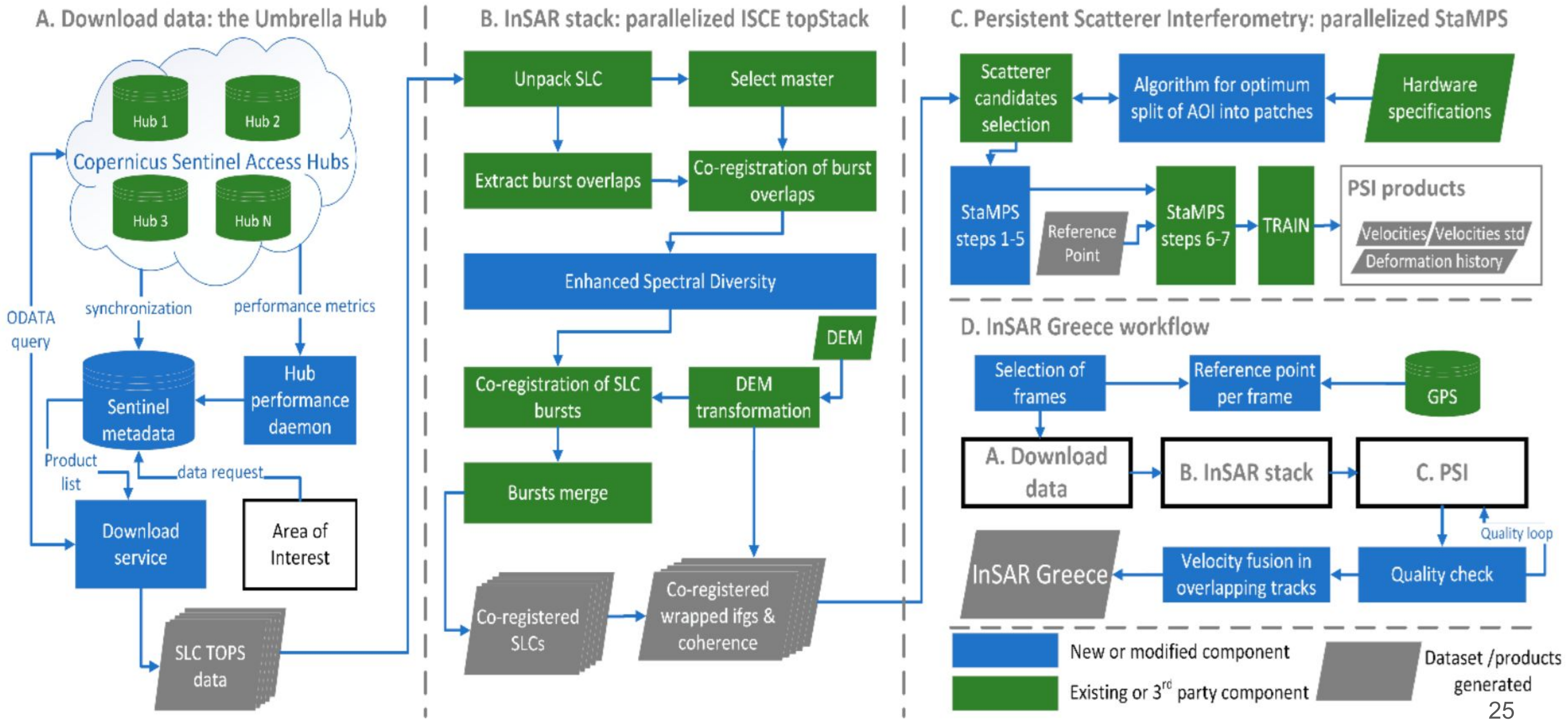
Alatza et al, 2020 (doi:10.3390/geosciences10080293)

Future Work

InSAR Greece

- islands
- update 2015 - 2022
- deformation papers (dissemination)

Parallelized-PSI (P-PSI) processing chain

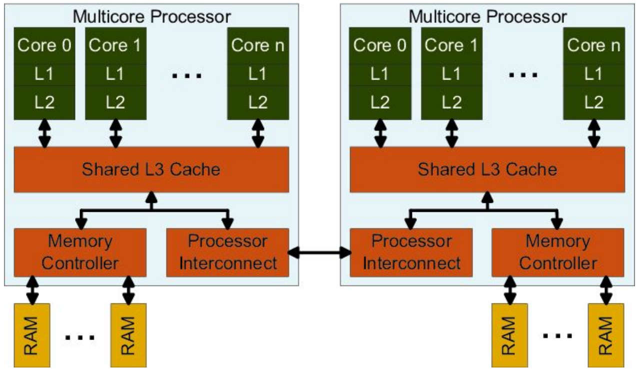


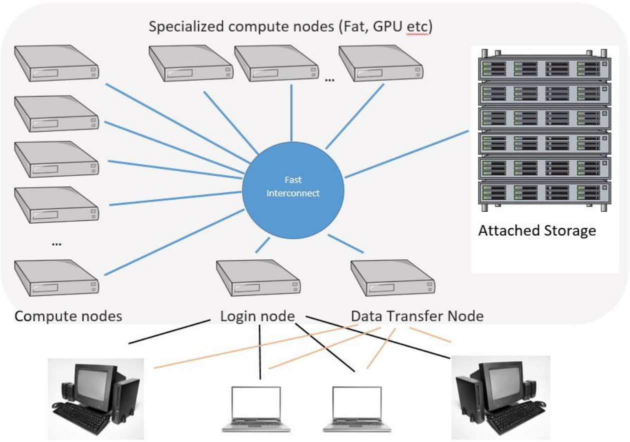
ISCE, StaMPS processing time performance optimization through parallel processing customization: P-PSI platform

ISCE and StaMPS software are not designed to fully exploit parallel or distributed resources. Simply installing on a system with such capabilities will only partially increase processing speed.

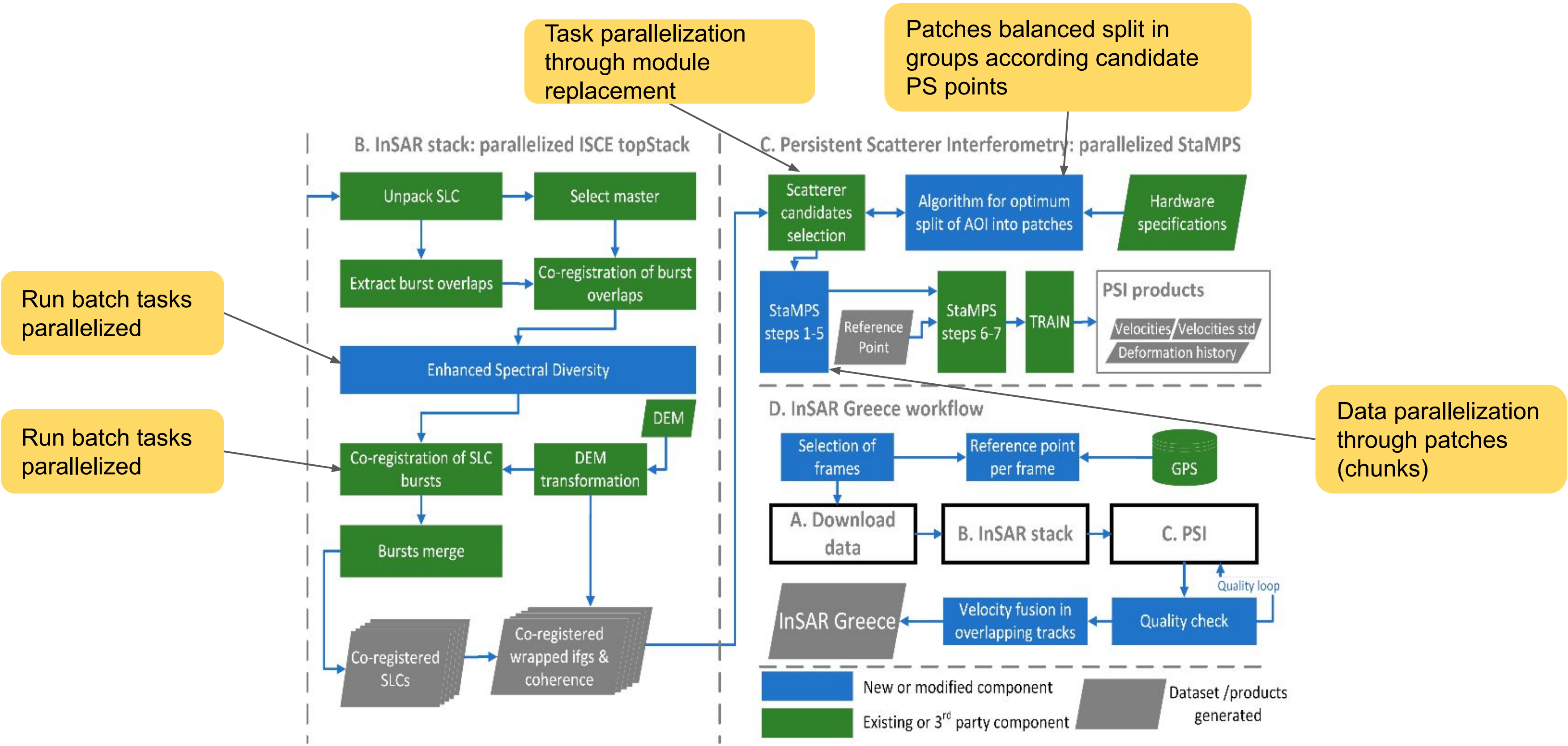
P-PSI customization main points

- Design to exploit the most of different parallel architectures: multi-core, multi CPU systems, server clusters, cloud platforms,
- Parallelize most demanding processing tasks
- Solve data-parallel problems and task-level parallelism using wrapper coding techniques to avoid large scale adaptations
- Result : 5 times faster processing on our 2x10 multithreaded CPU server



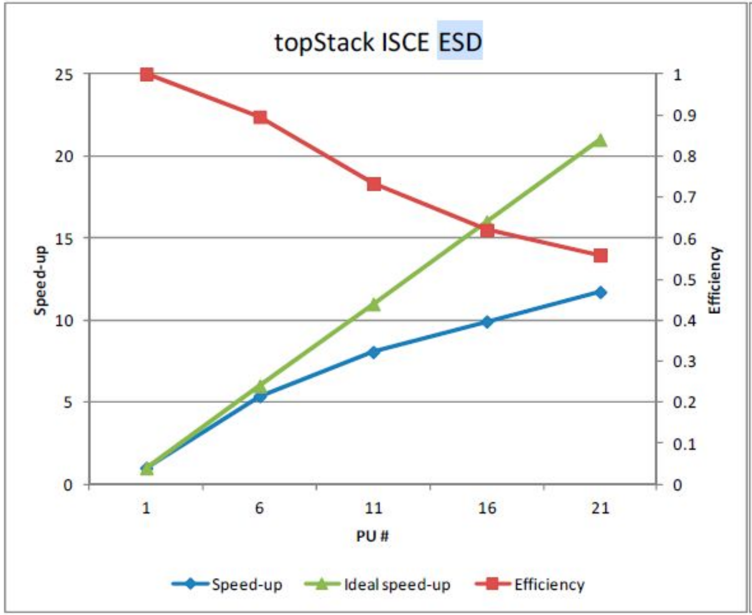


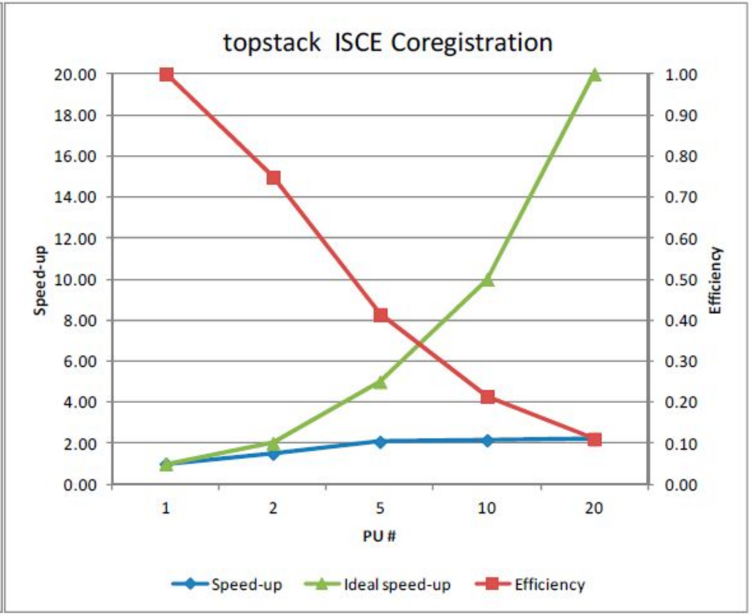
P-PSI Processing chain workflow: Parallelized steps



ISCE2 steps parallelization

- ISCE top-stack creates 10 sets of batch commands for the SLCt stack creation
- We parallelized the most time-consuming steps that did not exploit parallel resources by concurrent running of the processes that do not have any workflow dependencies
- Parallelized steps: Step 5 (ESD - coregistration of bursts overlaps) and Step 7 (Coregistration of SLC bursts)



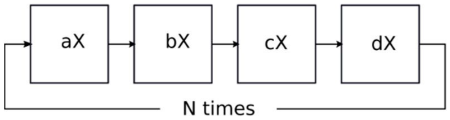


StaMPS steps parallelization

- StaMPS has the option to split the coregistered SLC stack into data chunks called “patches” forming a sort of grid.
- We parallelized the preprocessing of each patch (PS candidates extraction) developing a new python code module after decomposing the workflow dependencies

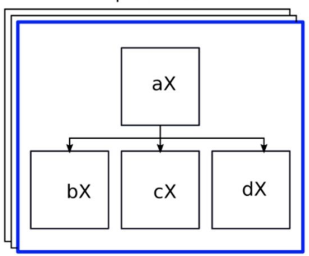
PS candidates extraction parallelization algorithm. (a. selection of candidates, b. coordinate calculation, c. Digital Elevation Model (DEM) calculation, d. phase calculation)

Split stack Sequential algorithm:
Repeat N times

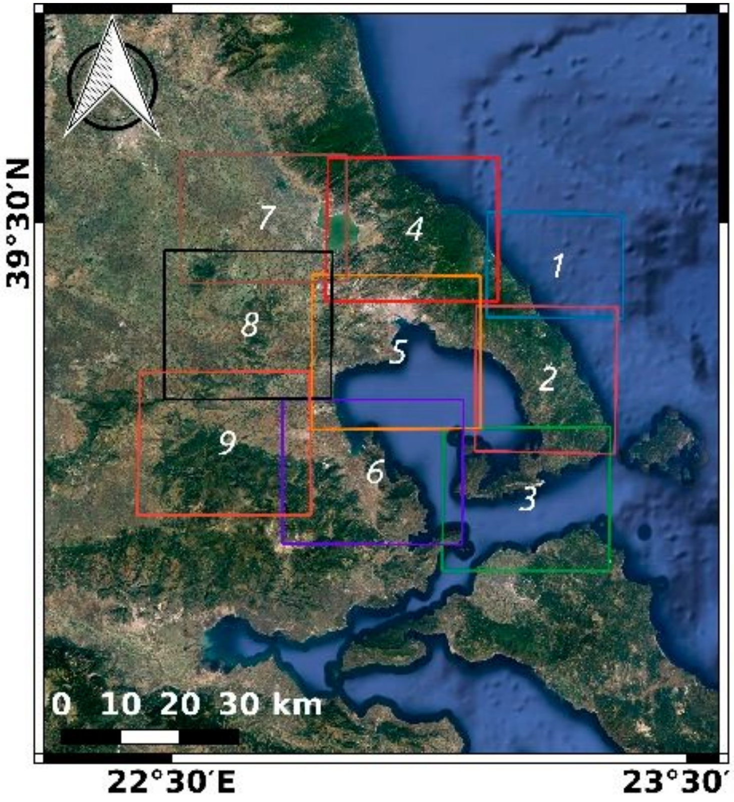


N: number of patches
n: CPUs
a: selection of candidates
b. coordinates calculation
c. DEM calculation
d. phase calculation
X: 1..N

Split stack Parallel algorithm:
Run up to n processes concurrently
Constrain:Start bX,cX,dX only if aX has finished for patch X



Cropped area split to patches



StaMPS steps parallelization

- StaMPS has the option to split the coregistered SLC stack into data chunks called “patches” forming a sort of a grid.
- Patches contain uneven number of data (PS candidate points) which is related with the land cover type.
- Example

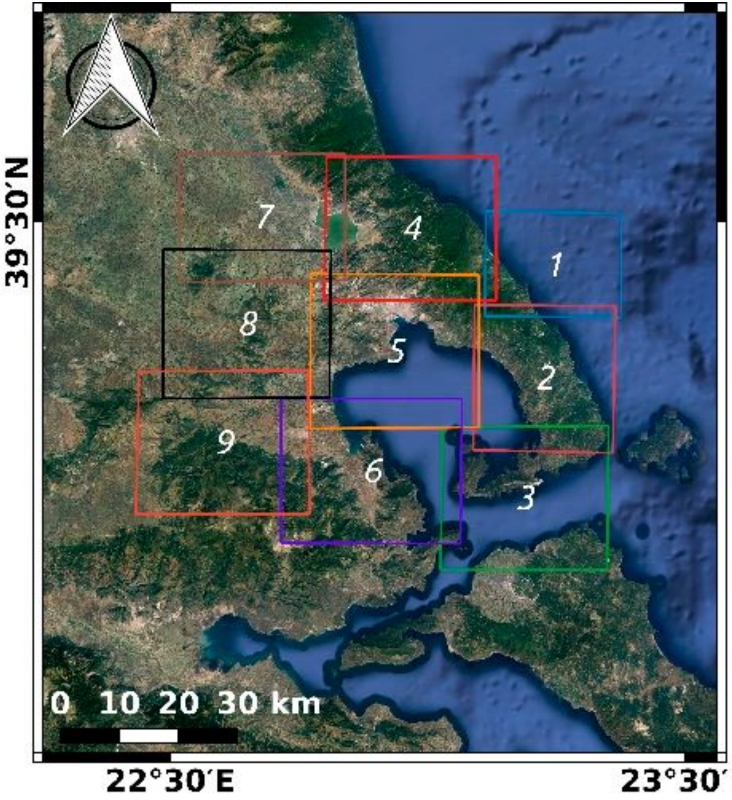
  We choose to split a cropped area on the map to 3x3 = 9 patches. PS candidates are much more dense in the rural areas (eg Patch 5 - Volos).

  In case 2 CPUs are available the embedded StaMPS algorithm split the patches in two groups, one for each CPU, determining a balanced number of patches i.e. patch 1-4 (total PS 7000) in the first group and patch 5-9 (tortal PS 33000) in the second.

  The processing time is proportional to the number of PS, not to the number of patches, so the algorithm we developed for the P-PSI platform split instead the patches in two groups balancing the number of PS candidates i.e. patch 5 (total PS 20000) in the first group and all other patches in group 2 (total PS 20000)

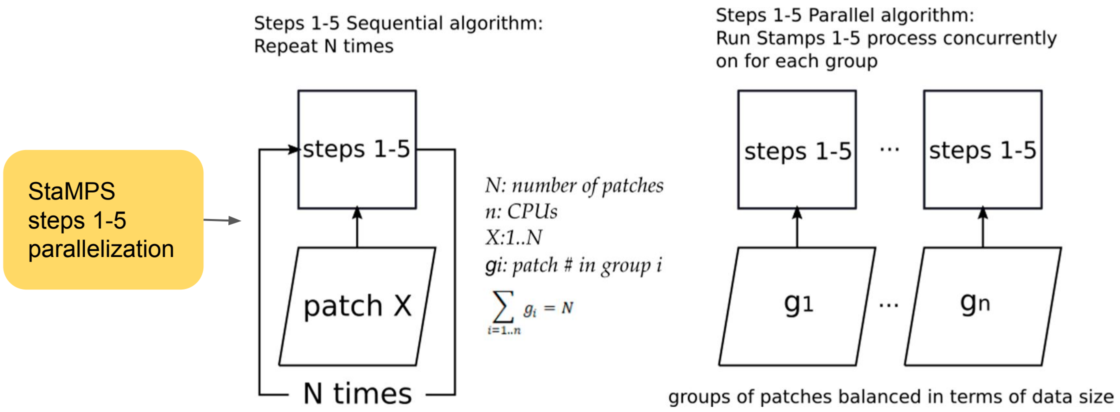
Cropped area split to patches

	num of PS cand.
Patch 1	500
Patch 2	1500
Patch 3	1000
Patch 4	4000
Patch 5	20000
Patch 6	4000
Patch 7	000
Patch 8	3000
Patch 9	3000
Sum	40000



StaMPS steps parallelization

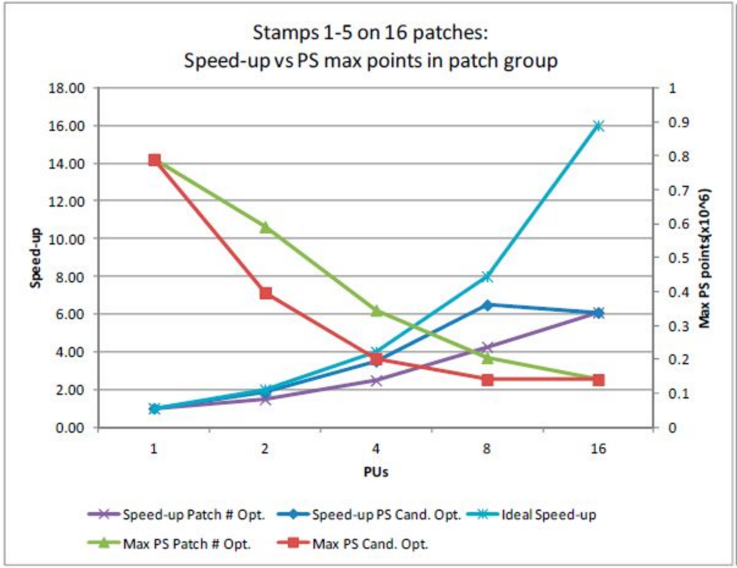
- Exploit the option to split input data (coregistered SLC stack) into patches applying concurrent processing on group of patches for each CPU
- Patches contain uneven PS candidate points which is proportional to the processing time. The parallized customization include algorithm to produce more balanced size of processing data (group of patches) for each concurrent process.
- Parallelize the preprocessing of each patch (PS candidates extraction) developing a new python code module after decomposing the workflow dependencies

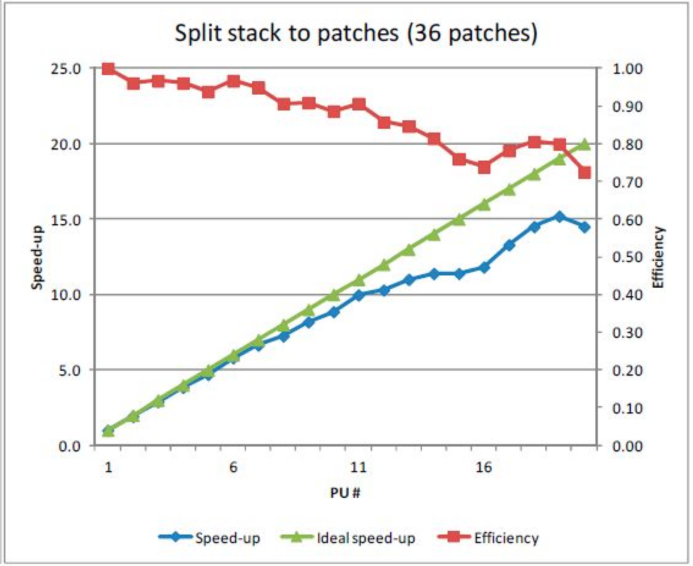


StaMPS steps parallelization performance benchmark

StaMPS 1-5 parallelization

PS candidates extraction





Processing chain time performance improvement

x5 faster processing

	Conventional PSI Method for the Full Sentinel-1 Frame		Our P-PSI Pipeline for the Full Sentinel-1 Frame		
Subprocess	Processing Time (h)	% of Subprocess Processing Time	Processing Time (h)	% of Subprocess Processing Time	Speed-up
ISCE2 preprocessing	23.0	6.46%	23.0	30.55%	1.0
ISCE2 ESD	19.4	5.44%	1.7	2.20%	11.7
ISCE2 SLC coregistration	36.3	10.21%	15.8	20.97%	2.3
ISCE2 wrap-up	1.5	0.42%	1.5	2.00%	1.0
PS candidates selection (mt_prep)	5.3	1.50%	0.3	0.36%	20.0
Stamps 1–5	270.0	75.96%	33.0	43.93%	8.2
Total	355.4	100.00%	75.1	100.00%	4.7

Both ISCE and StaMPS in their latest releases still need P-PSI developed parallelization add-ons to exploit multiple processor resources

A latest release of P-PSI is recently installed (under testing) on an NTUA virtual machine

Papoutsis, I.; Kontoes, C.; Alatza, S.; Apostolakis, A.; Loupasakis, C. InSAR Greece with Parallelized Persistent Scatterer Interferometry: A National Ground Motion Service for Big Copernicus Sentinel-1 Data. *Remote Sens.* **2020**, *12*, 3207. https://doi.org/10.3390/rs12193207