Automatized Sentinel-1 Monitoring System

Milan Lazecký, Ph.D.
milan.lazecky@vsb.cz

IT4Innovations
national00£$1!
supercomputing
center000#1010

Background

- 1980s - satellite (SAR) radar images are interferometrically coherent!
- 1990s - satellite SAR interferometry (InSAR) has potential to identify subsidence and landslides!
- 2000 - PS-InSAR technique can identify (sub)millimetric motions!
- 2008 - TerraSAR-X satellite offers ground resolution < 1x1 m!
- 2014 - new SAR satellite Sentinel-1 = "golden era of InSAR"
- 2016 - approaches towards (inter)national systems for monitoring of terrain displacements, InSAR recognized and approved by geodetists

Work objective(s)

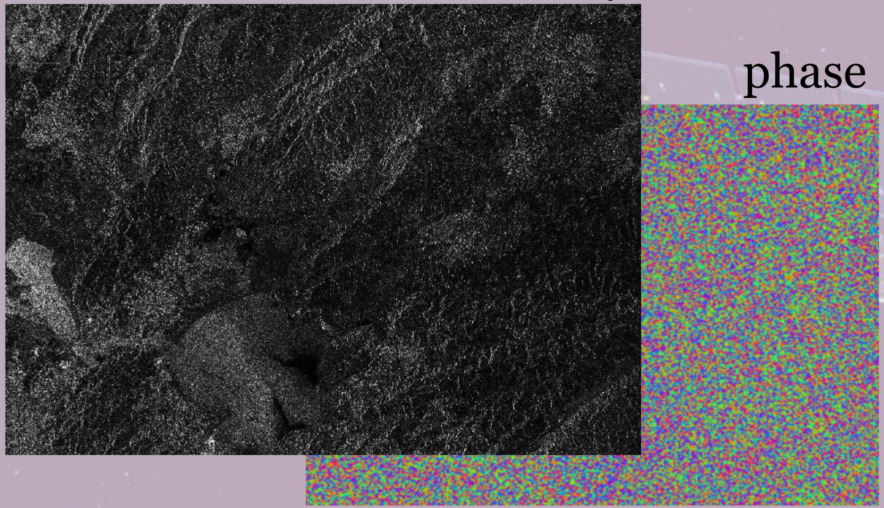
- to create a Czech national terrain monitoring system offering:
  - generation of annual static maps of terrain motions - subsidence, active landslides
  - on-demand generation of high resolution motion maps over urban areas
  - "near real-time" warning system for potential sudden motions
  - extra radar-based feature maps - e.g. dual-polarization application for forestry/agriculture (identification of land type and/or deforestation)

Satellite SAR Interferometry

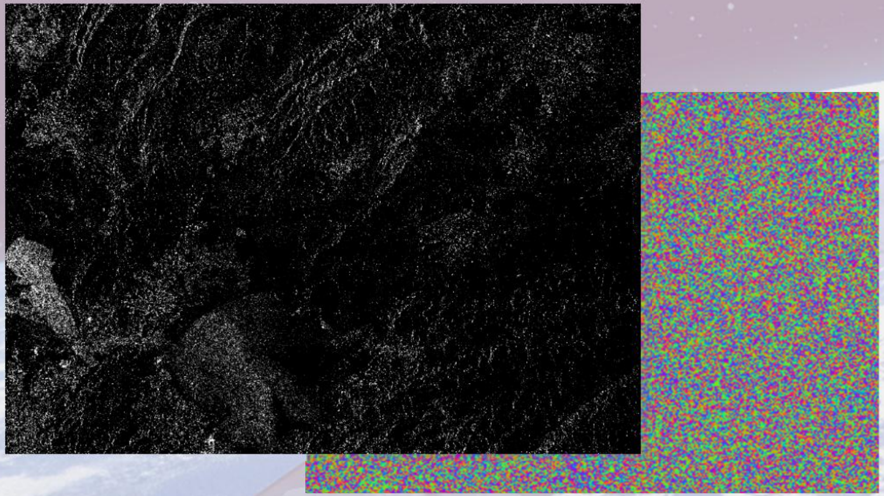
intensity

time 1

phase



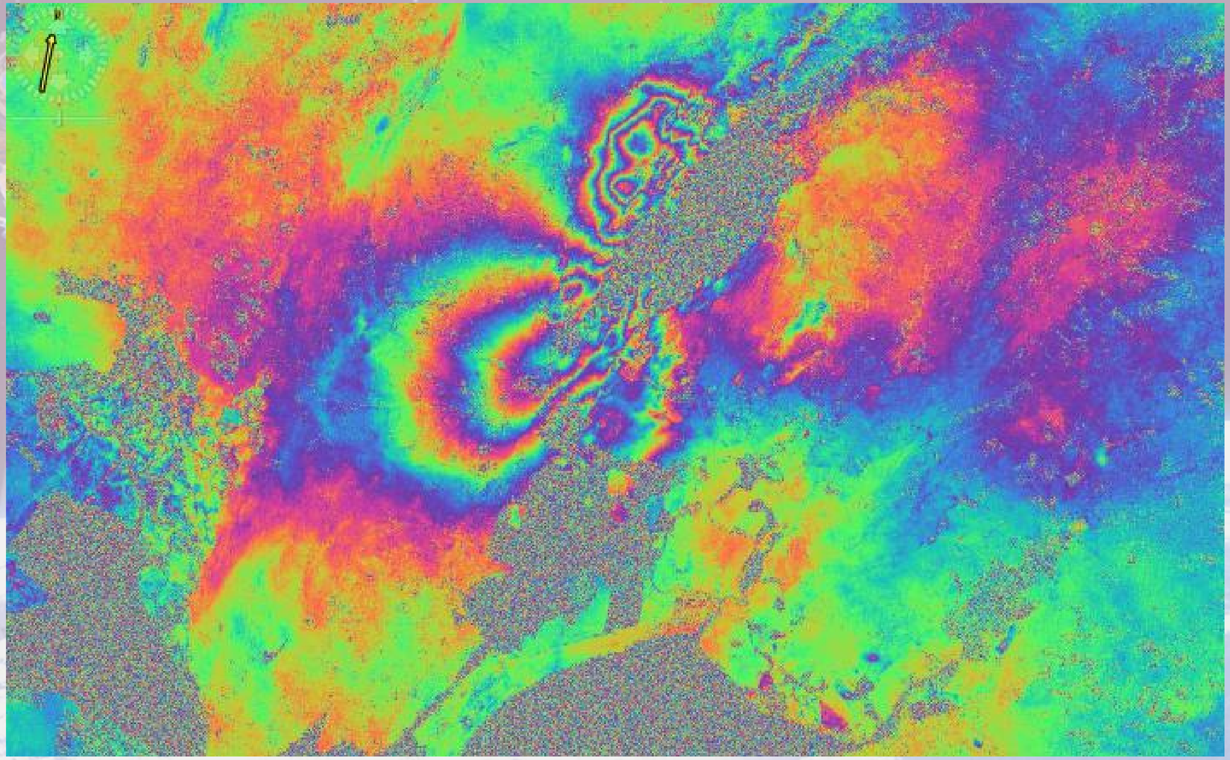
minus



time 2

=

phase interferogram



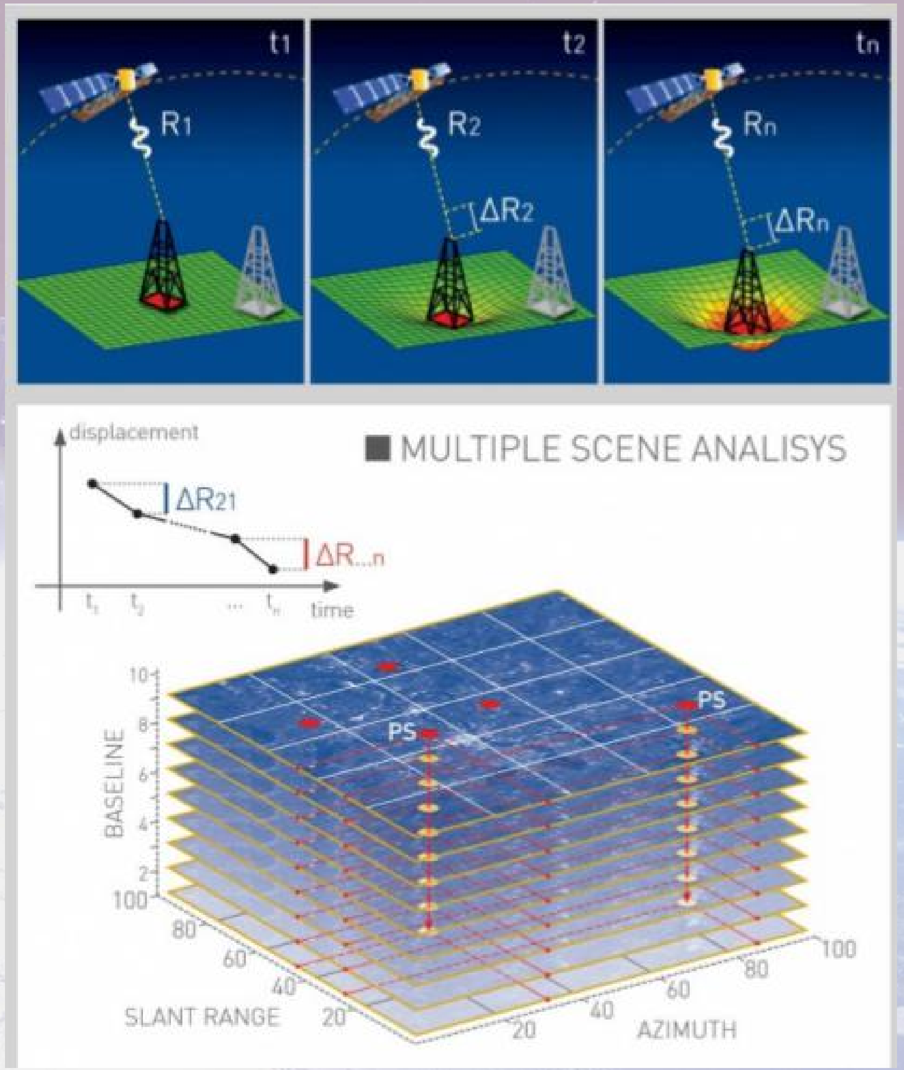
(earthquake in Napa valley, 2014)

Multitemporal InSAR

- usage of 20+ SAR images
- selection of stably reflecting objects
- removal of atmospheric and other noise components

<u>Basic techniques:</u>

- **Persistent Scatterers (PS-InSAR)**
  - combination of images with common "master"
  - high accuracy of estimation (<1 mm/year)
- **Small Baselines (SB-InSAR)**
  - combination of images with short time span
  - spatial filtering -> more points, lower accuracy



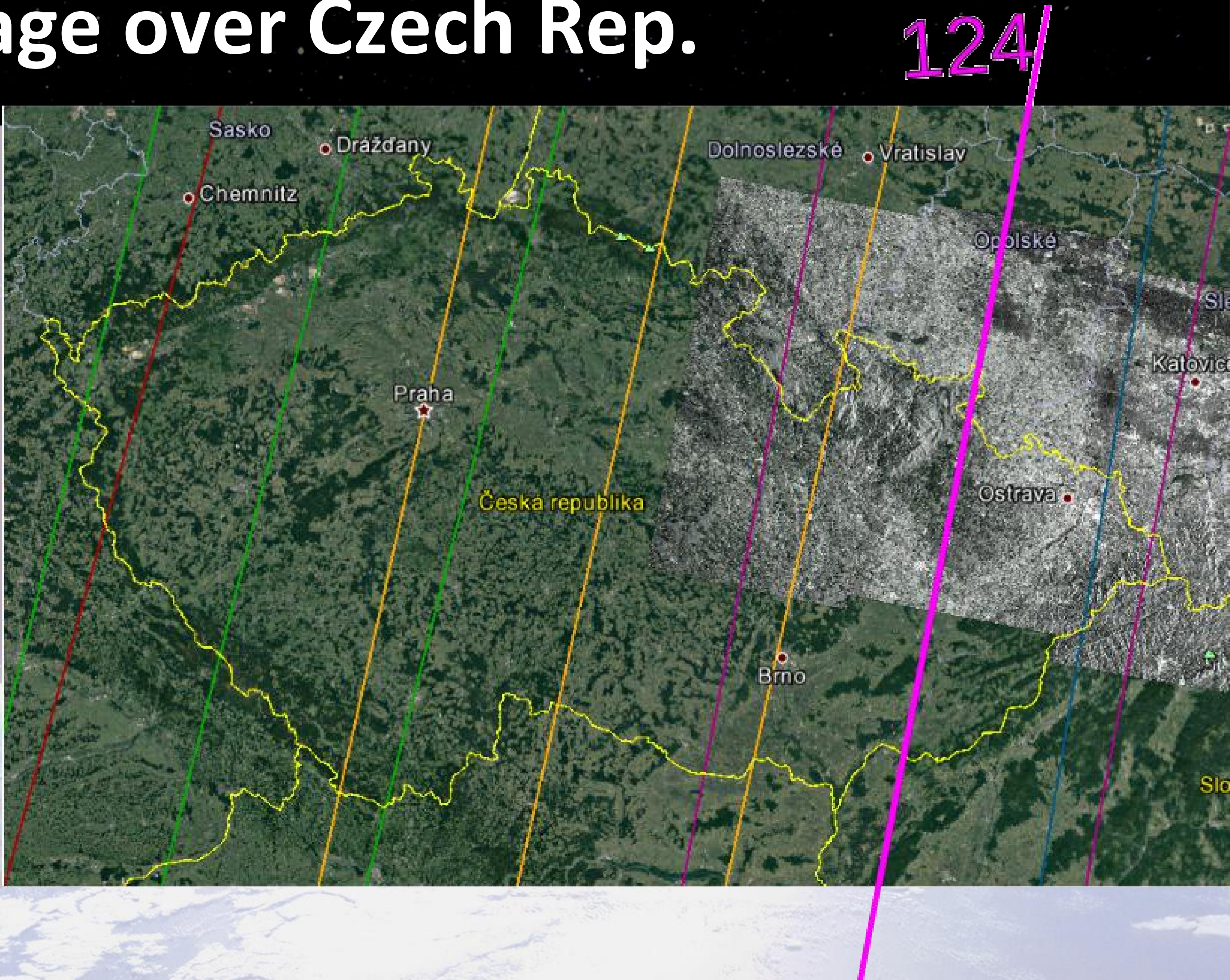
Sentinel-1, a "game-changer"

- part of European Copernicus fleet
- **free and open data access**
- global data (with higher revisit rate over Europe) since Oct 2014
- 6 days revisit time (for InSAR purposes)
- resolution of 20x5 m
- 1 image = cca 250x180 km = cca 4.5 GB

  ---> need of supercomputations

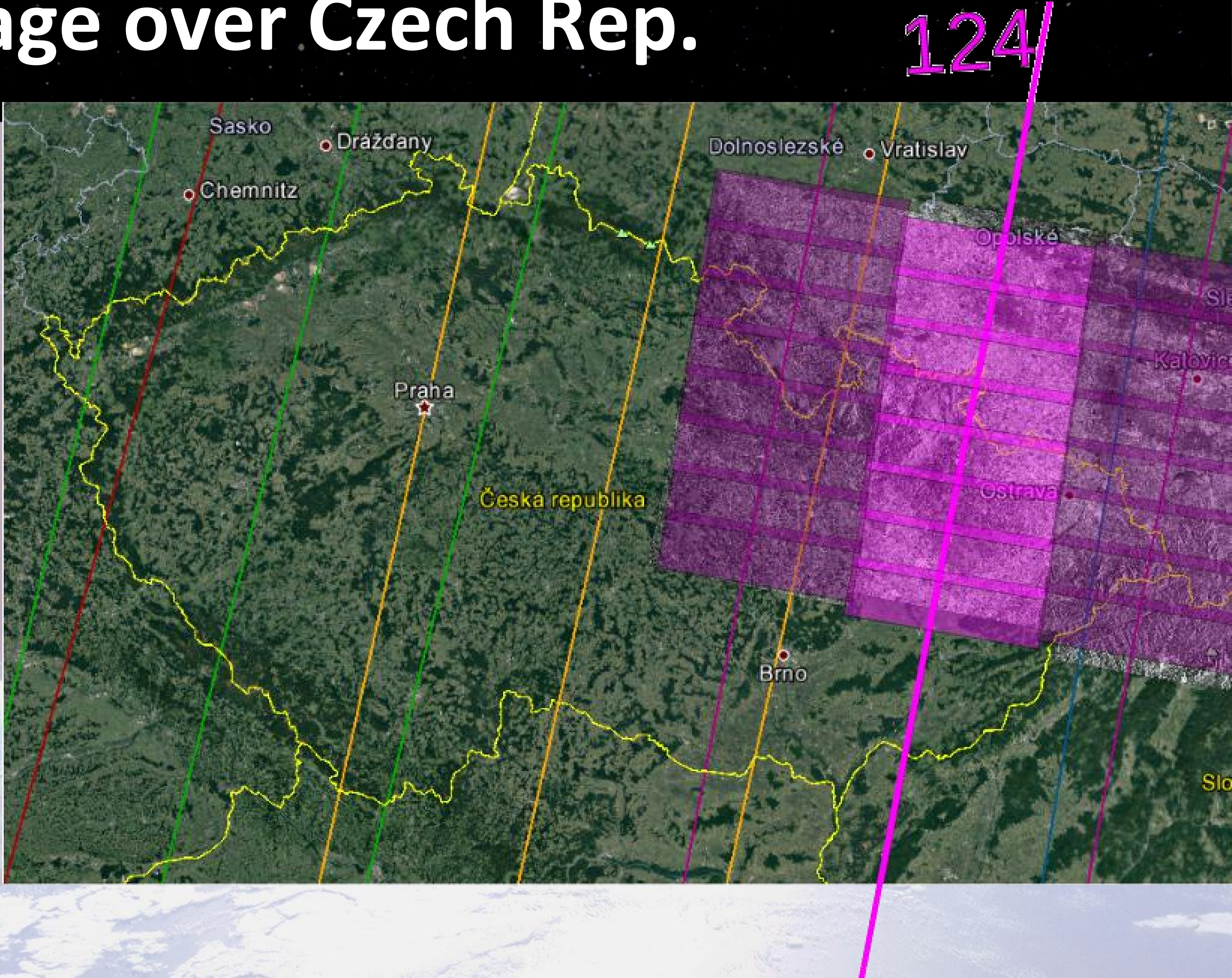
Sentinel-1 coverage over Czech Rep.

- 4 descending(D) tracks
  - footprints pictured ->
- 4 ascending (A) tracks
- example:
  - 1 image of D track 124



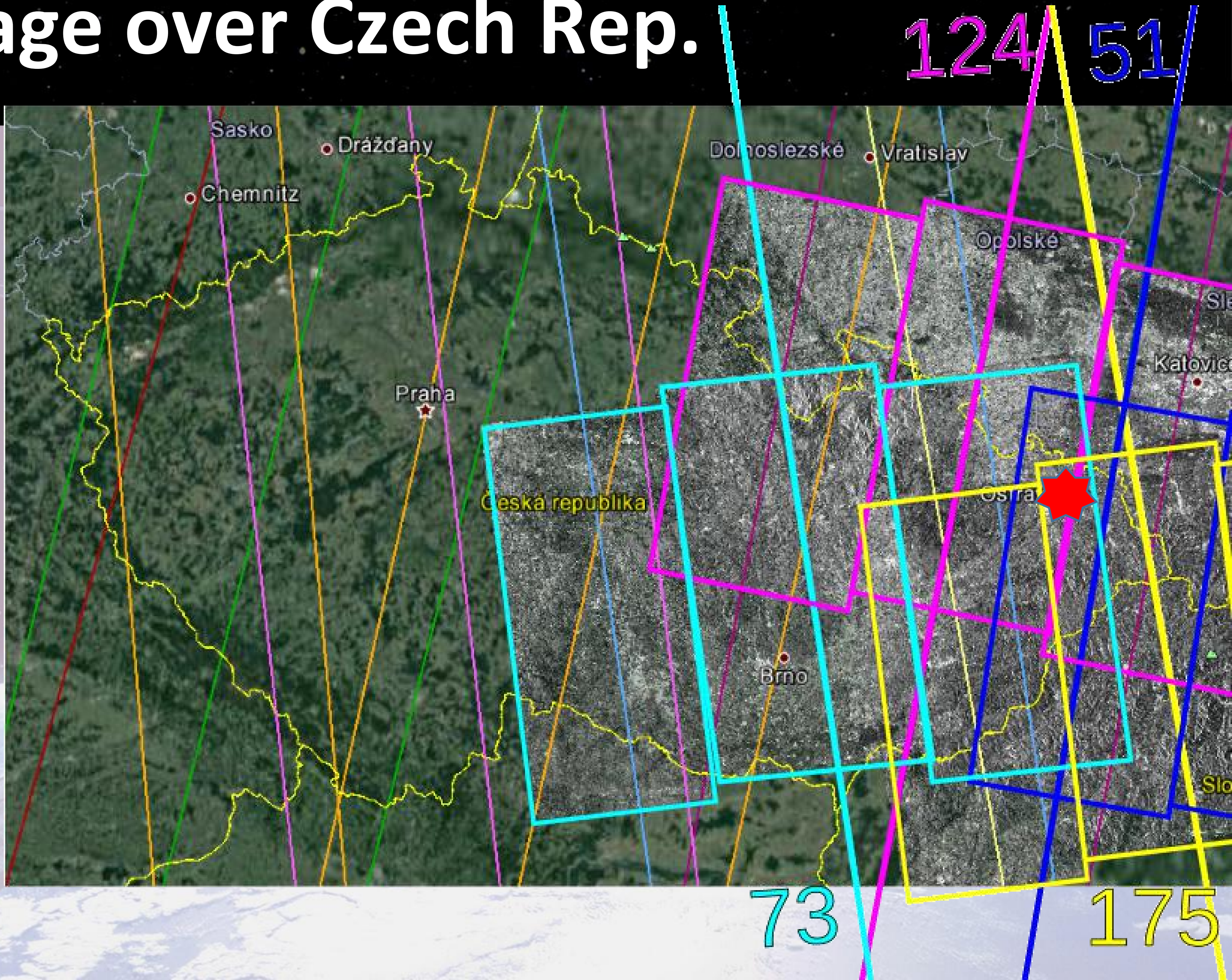
Sentinel-1 coverage over Czech Rep.

- 1 image consists of:
  - 3 swaths
  - 3x8 bursts (80x20 km)



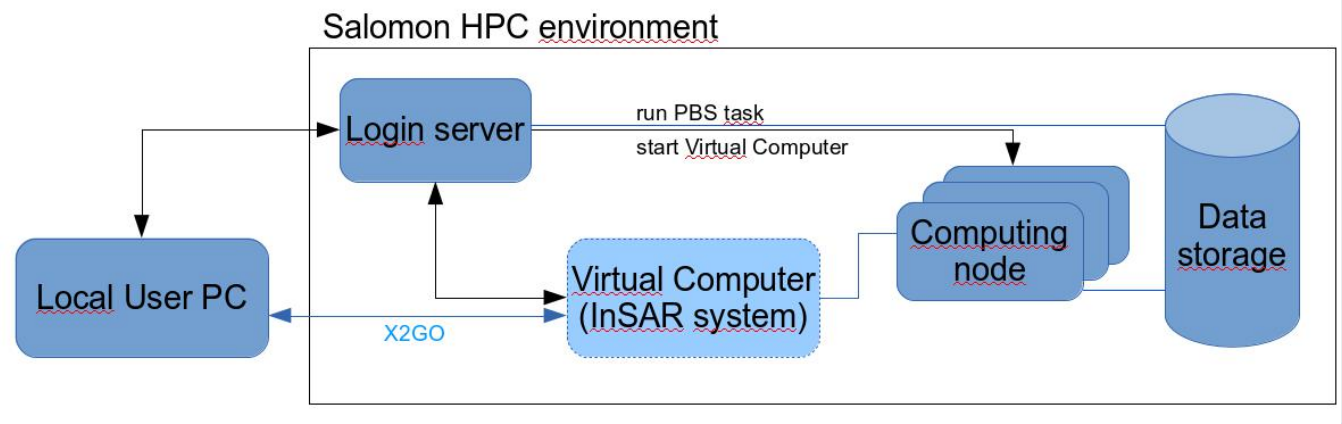
Sentinel-1 coverage over Czech Rep.

- each area covered by 2 D and 2 A tracks
- processing of all tracks leads to self-confirmed results
- ~60 images/year -> 4 tracks x 60 images x 4.5 GB = 1 TB => processing of any 1 area needs 1 TB of input data

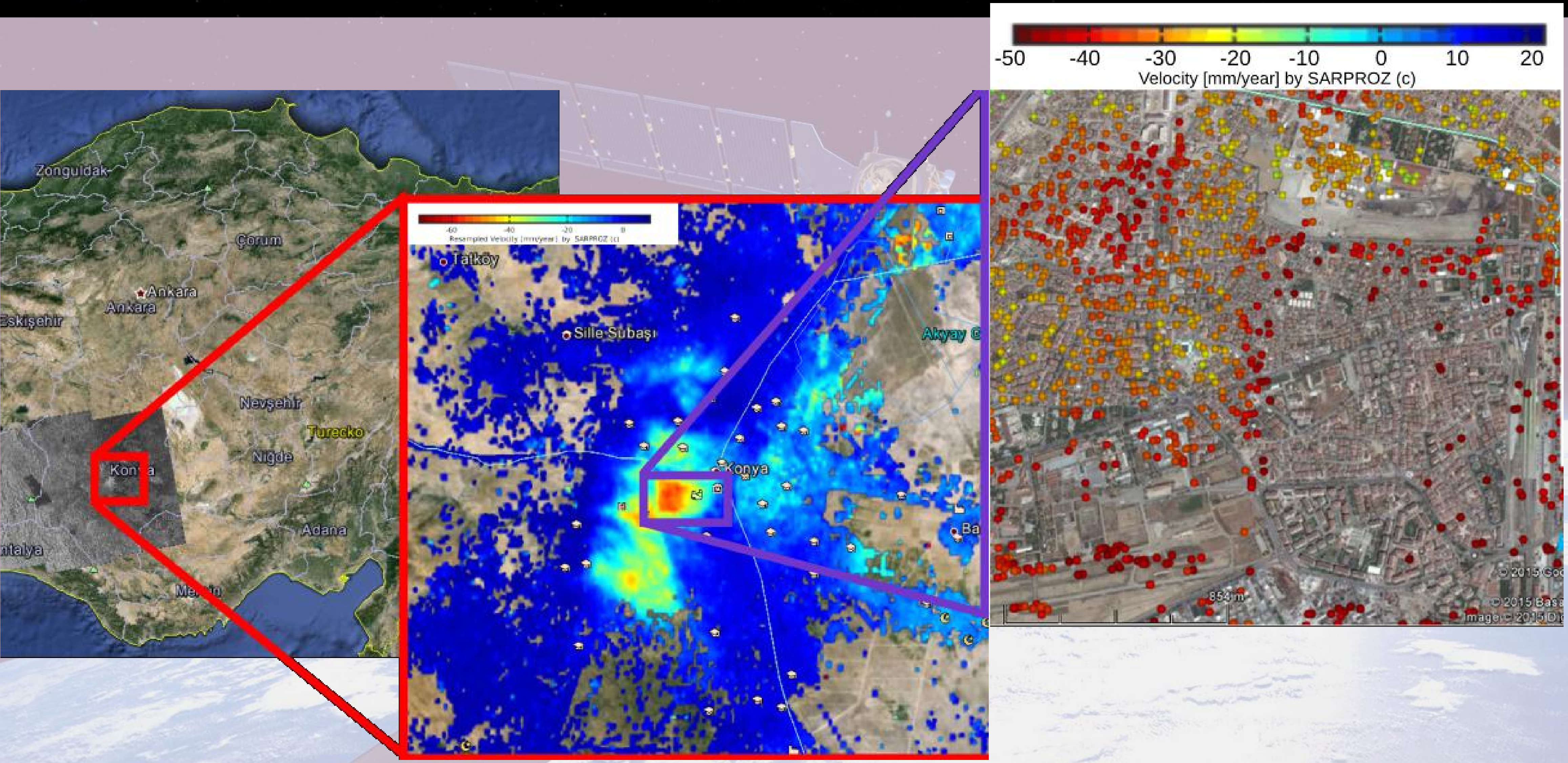


2015: HPC processing system 1.0 - "IT4InSAR"

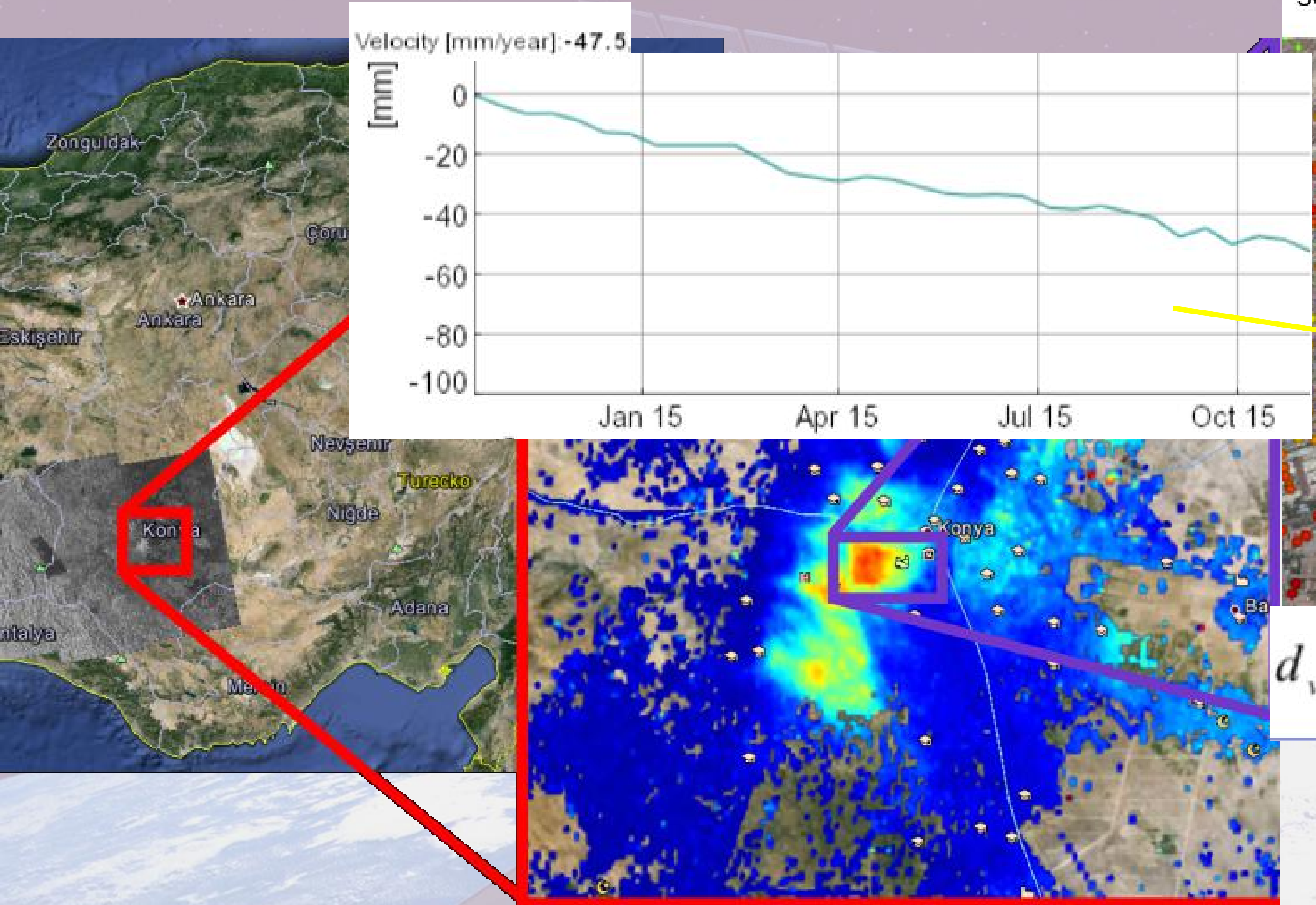
- virtual machine running specific software on one node (24 cores)
- quick and flexible for one-off processing and testing, sharable platform
- convenient but "no-HPC"
- empowered by SARPROZ sw

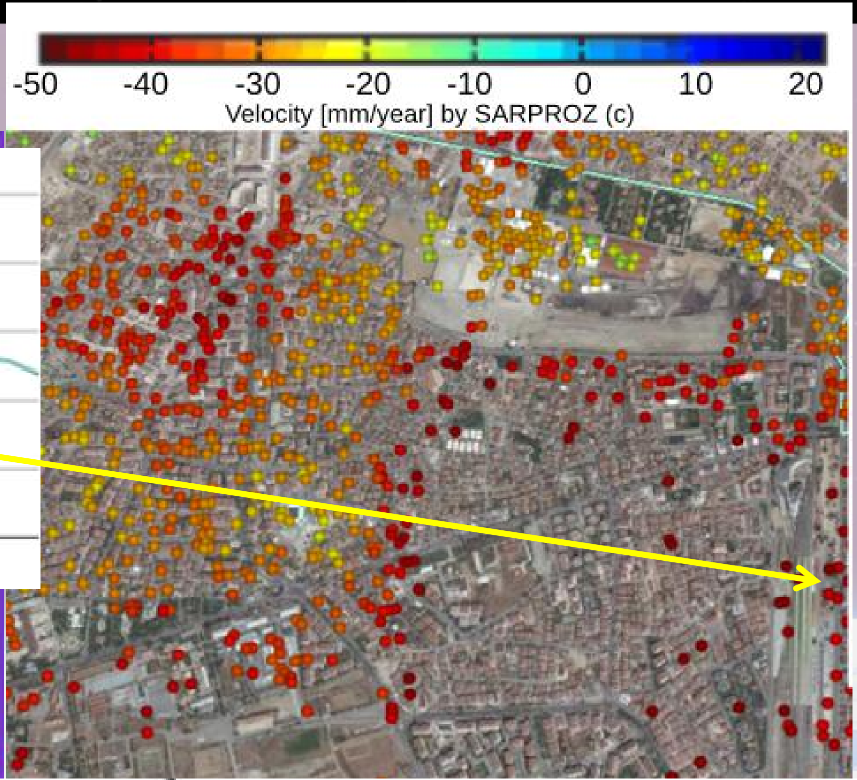


2015: HPC processing system 1.0 - "IT4InSAR"



2015: HPC processing system 1.0 - "IT4InSAR"



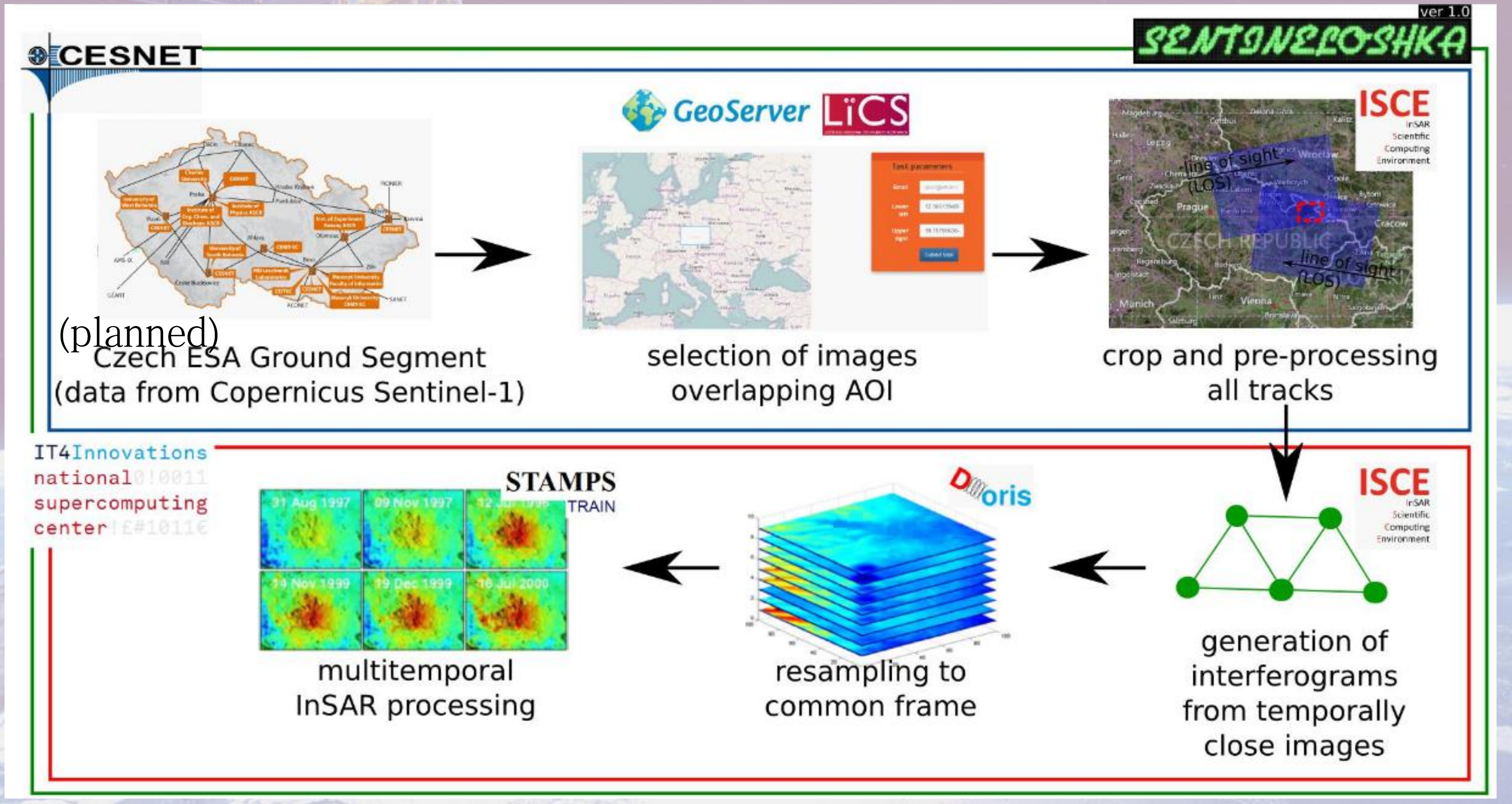


$$d_v = \frac{d_{LOS}}{\cos\theta_{inc}}$$ 47.5/cosd(38.3)=**61+-2.5 mm/yr**

Permanent GPS : subsidence rate from 2014 April to 2015 Aug is: -82 (mm), 1.92 (SD) which means **61 mm/yr**

2016: HPC processing system 2.0 - "Sentineloshka"

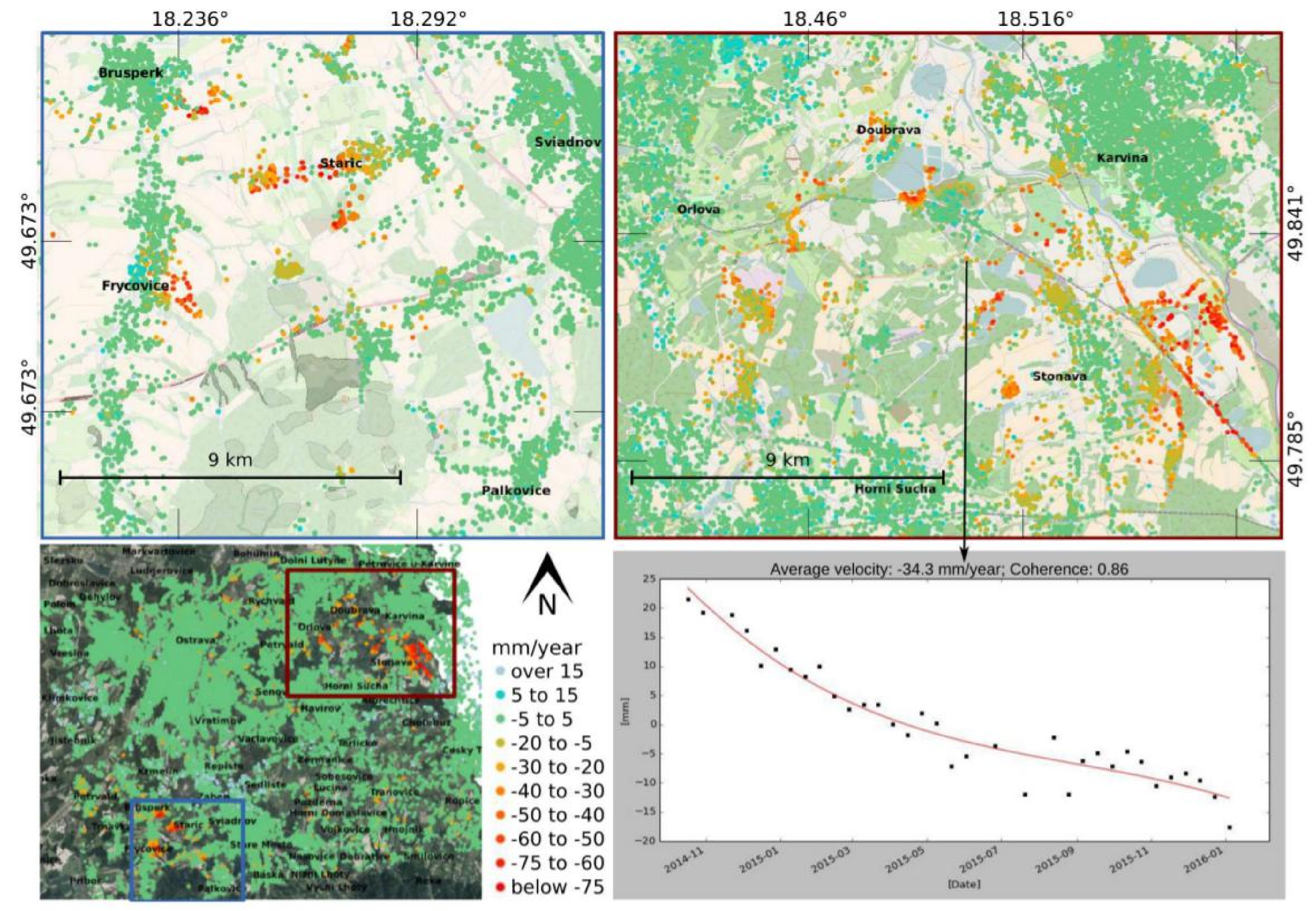
- processing using open-source tools, custom Sentinel-1 database
- codes available: https://github.com/espiritocz/sentineloshka/
- fully automatic
  - user input: coordinates
- heavy processing
  - need optimizations



2016: HPC processing system 2.0 - "Sentineloshka"

first result:

- 50x50 km area
- 2 years data: 3.8 TB
- 650 core-hours (!)

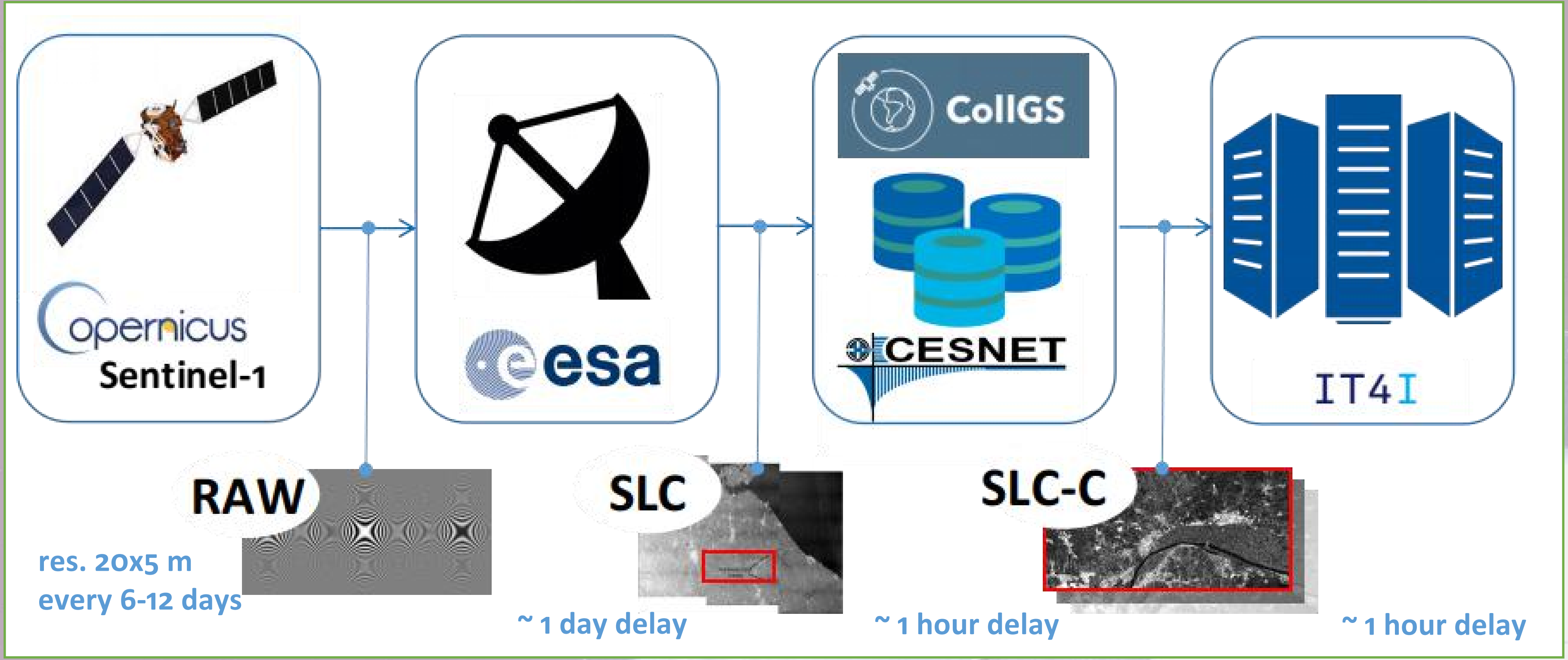


ISCE InSAR Scientific Computing Environment

STAMPS TRAIN

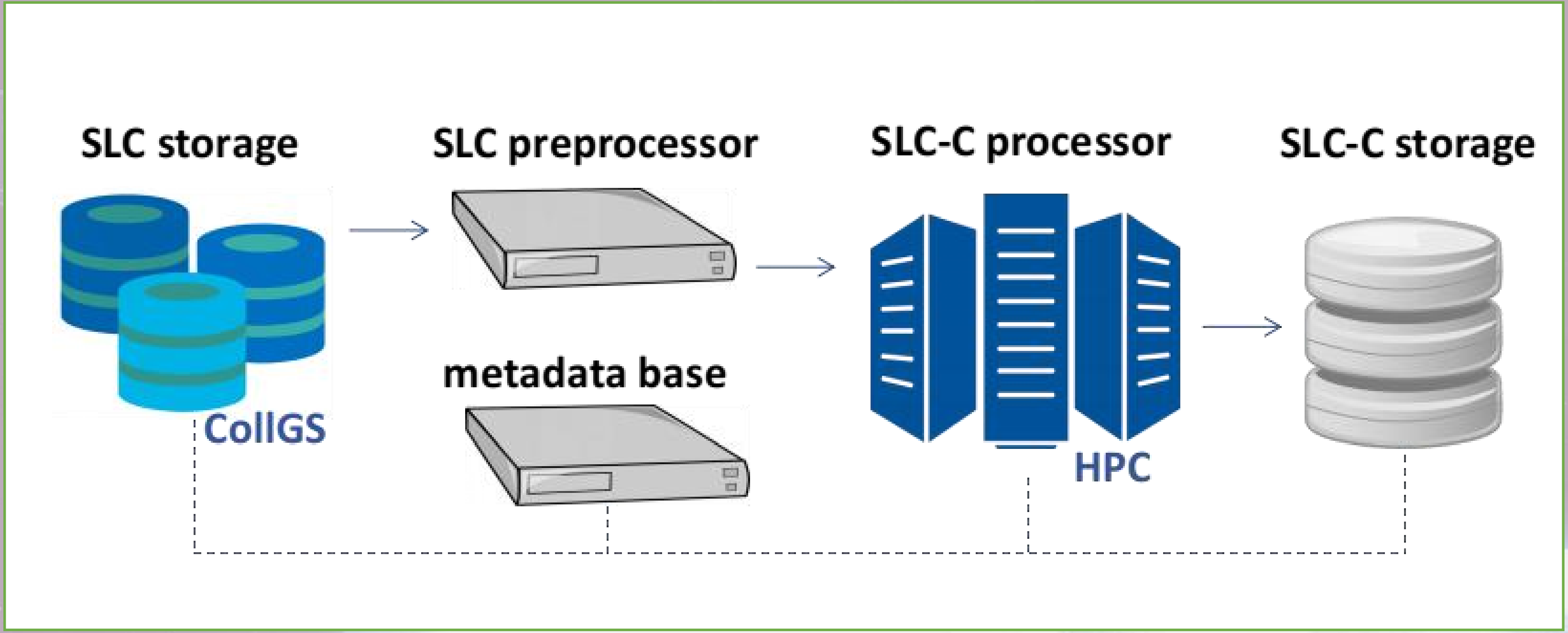
LiCS LOOKING INSIDE THE CONTINENTS FROM SPACE

2017: HPC processing system 3.0 - IT4S1



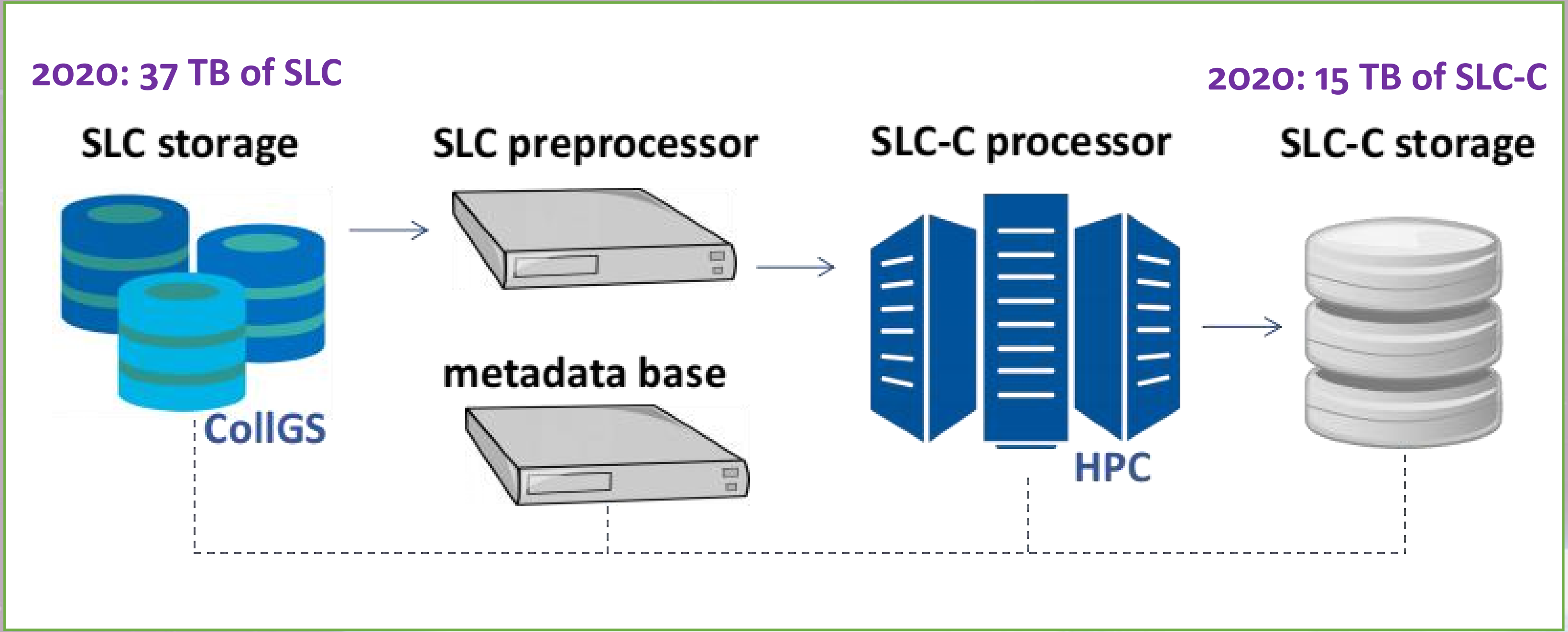
- ESA transforms raw satellite data into SLC (images that include radar wave phase information)
- CollGS stores SLC data over Czech Republic
- IT4I exploits SLC data and calibrates/coregisters them (0.001 px precision)

2017: HPC processing system 3.0 - IT4S1



- SLC preprocessor (CESNET server) - calibrates data using precise ephemerides and auxilliary Sentinel-1 data, sends data to IT4I 10 minutes/18 bursts
- metadata base (CESNET server) - S1 burst metadb based on LiCS
- SLC-C generation (IT4I) - (heavy) HPC processing, storage 20 minutes/18 bursts

2017: HPC processing system 3.0 - IT4S1



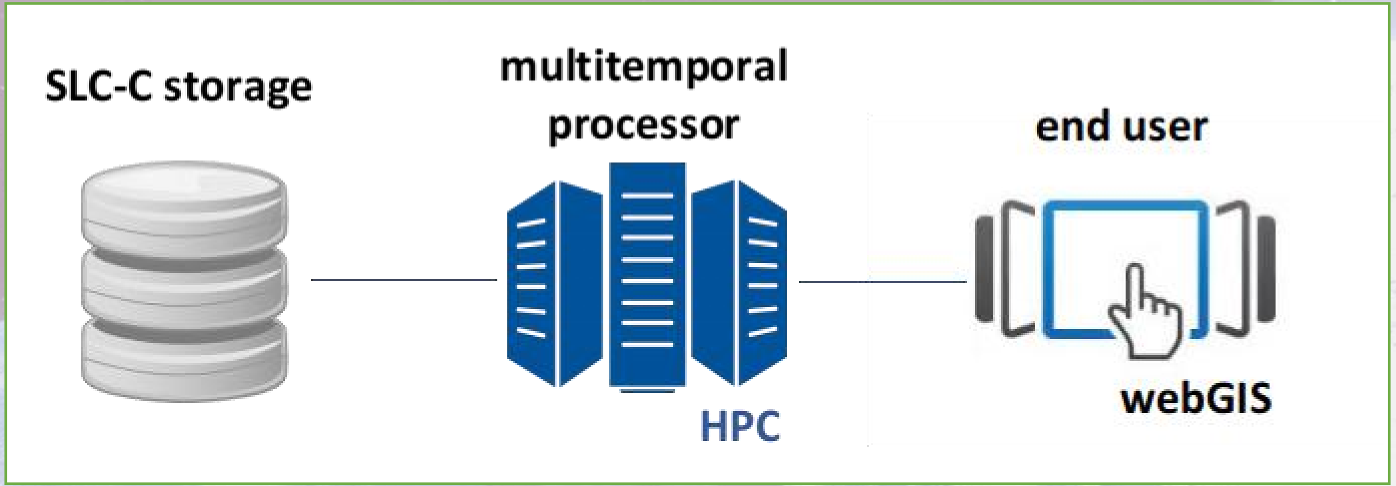
- SLC preprocessor (CESNET server) - calibrates data using precise ephemerides and auxilliary Sentinel-1 data, sends data to IT4I 10 minutes/18 bursts
- metadata base (CESNET server) - S1 burst metadb based on LiCS
- SLC-C generation (IT4I) - (heavy) HPC processing, storage 20 minutes/18 bursts

2017: HPC processing system 3.0 - IT4S1

- SLC-C data are organized per track and burst ID
- user sets coordinates, data are sent for processing, results are seen in a webGIS
- currently available:
  - DInSAR - one burst interferogram is generated in 8 seconds
  - PS InSAR - using STAMPS, dataset of 100 bursts: 1-2 hours, i.e. 24-48 core-hours
  - SB InSAR - using STAMPS, dataset of 300 bursts: 3-4 hours, i.e. 72-96 core-hours

including previous preprocessing: ~2 min./burst

both PS and SB processing should be more optimized



ISCE
InSAR Scientific Computing Environment

STAMPS
TRAIN

IT4S1 - first results


Novinky.cz

Hlavní stránka » Domácí

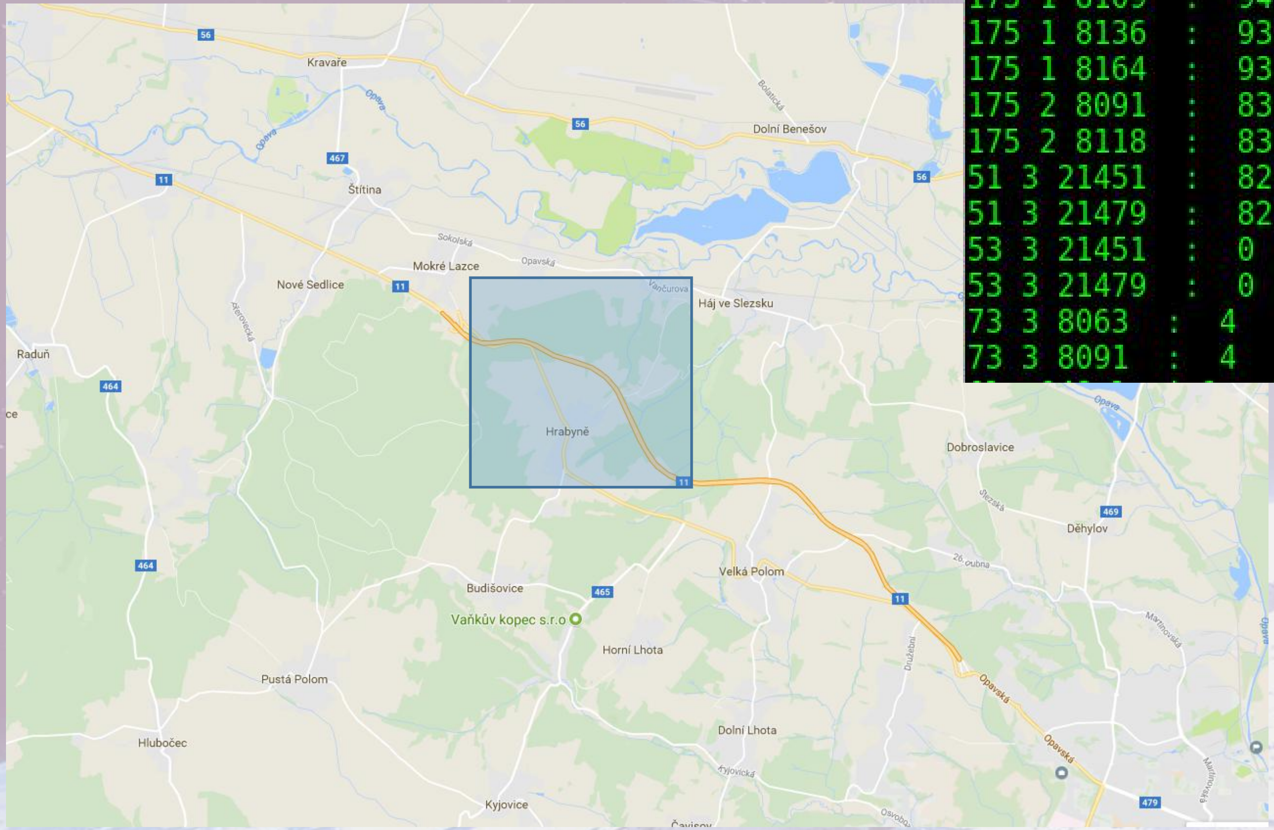
Další problém Eurovie. U nové cesty spadla část zd

Velké štěstí měli řidiči projíždějící na nedávno otevřené čtyřproudové silnici I/11 mezi Ostravou a Opavou. Podél vozovky se na úrovni obce Hrabyně v pondělí zřítila část tzv. gabionové zdi, tedy zdi vytvořené z kovových sítí a kamenné výplně.

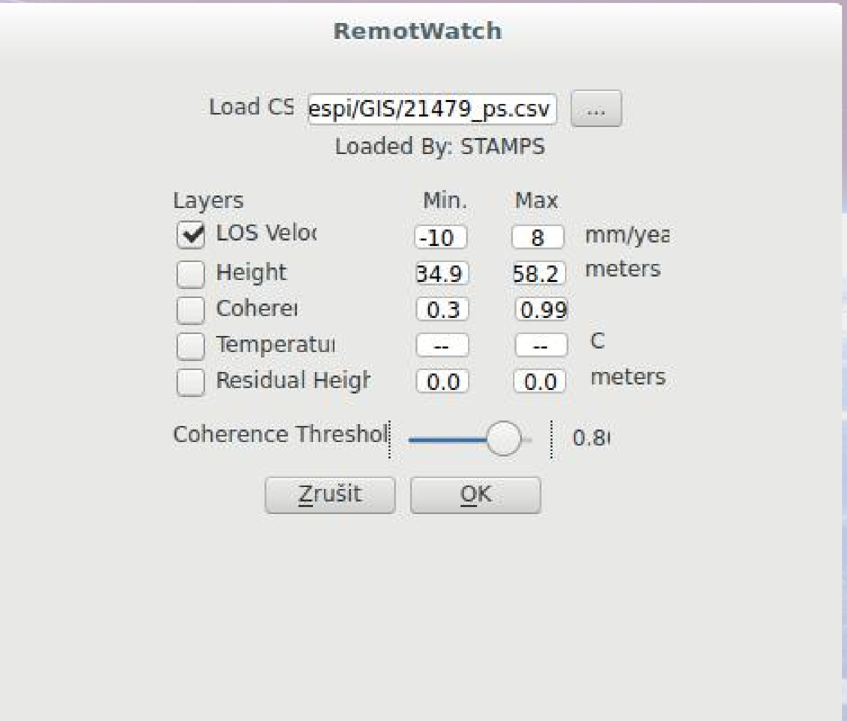
středa 20. září 2017, 13:52

▲ Na Opavsku se sesunula část gabionové stěny u silnice I/11. Úsek rychlostní

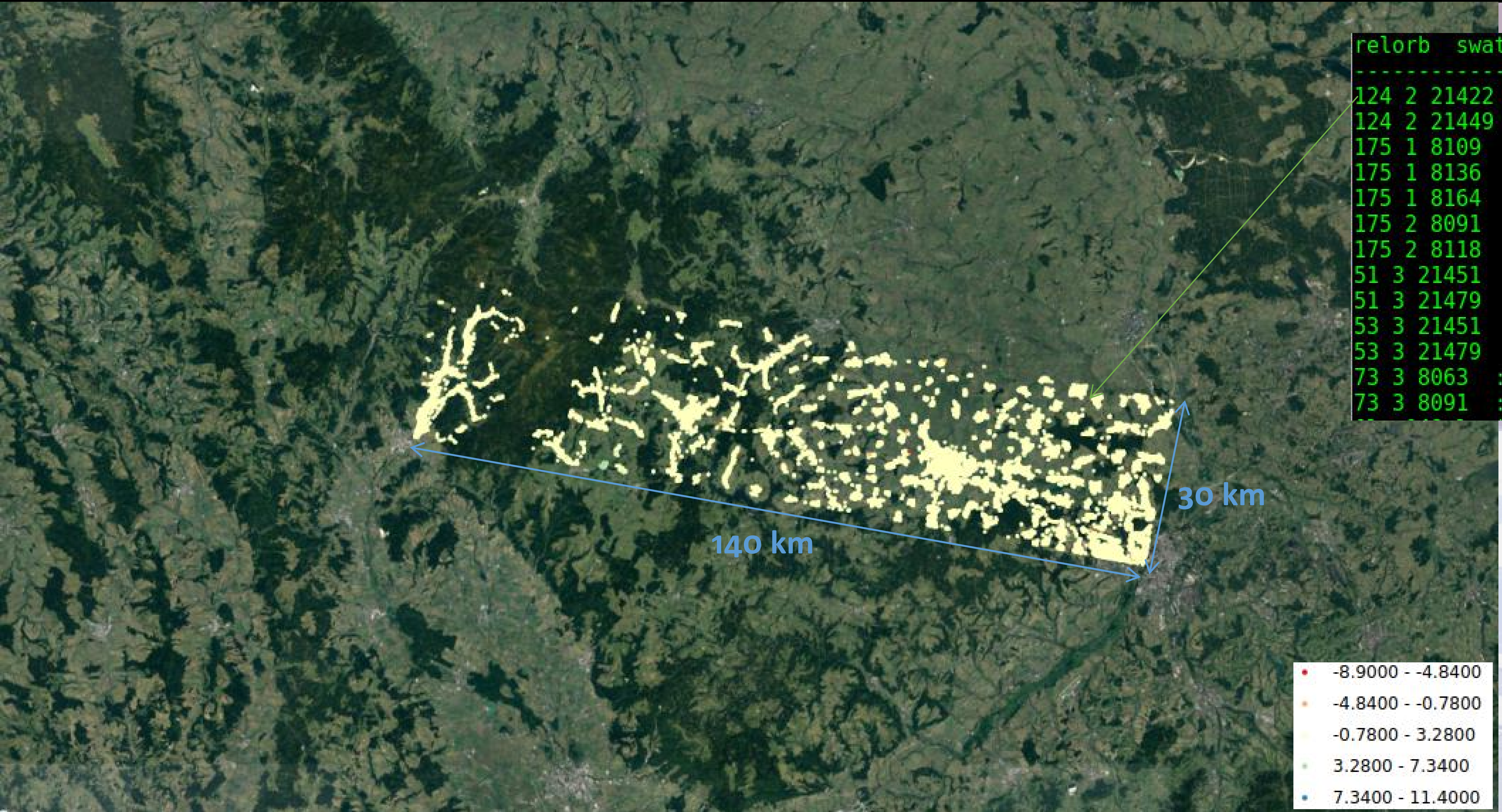
IT4S1 - first results




```
relorb  swath  burstid  :  imageno
----------------------------------
124 2 21422  :  108
124 2 21449  :  108
175 1 8109  :  94
175 1 8136  :  93
175 1 8164  :  93
175 2 8091  :  83
175 2 8118  :  83
51 3 21451  :  82
51 3 21479  :  82
53 3 21451  :  0
53 3 21479  :  0
73 3 8063  :  4
73 3 8091  :  4
```



IT4S1 - first results

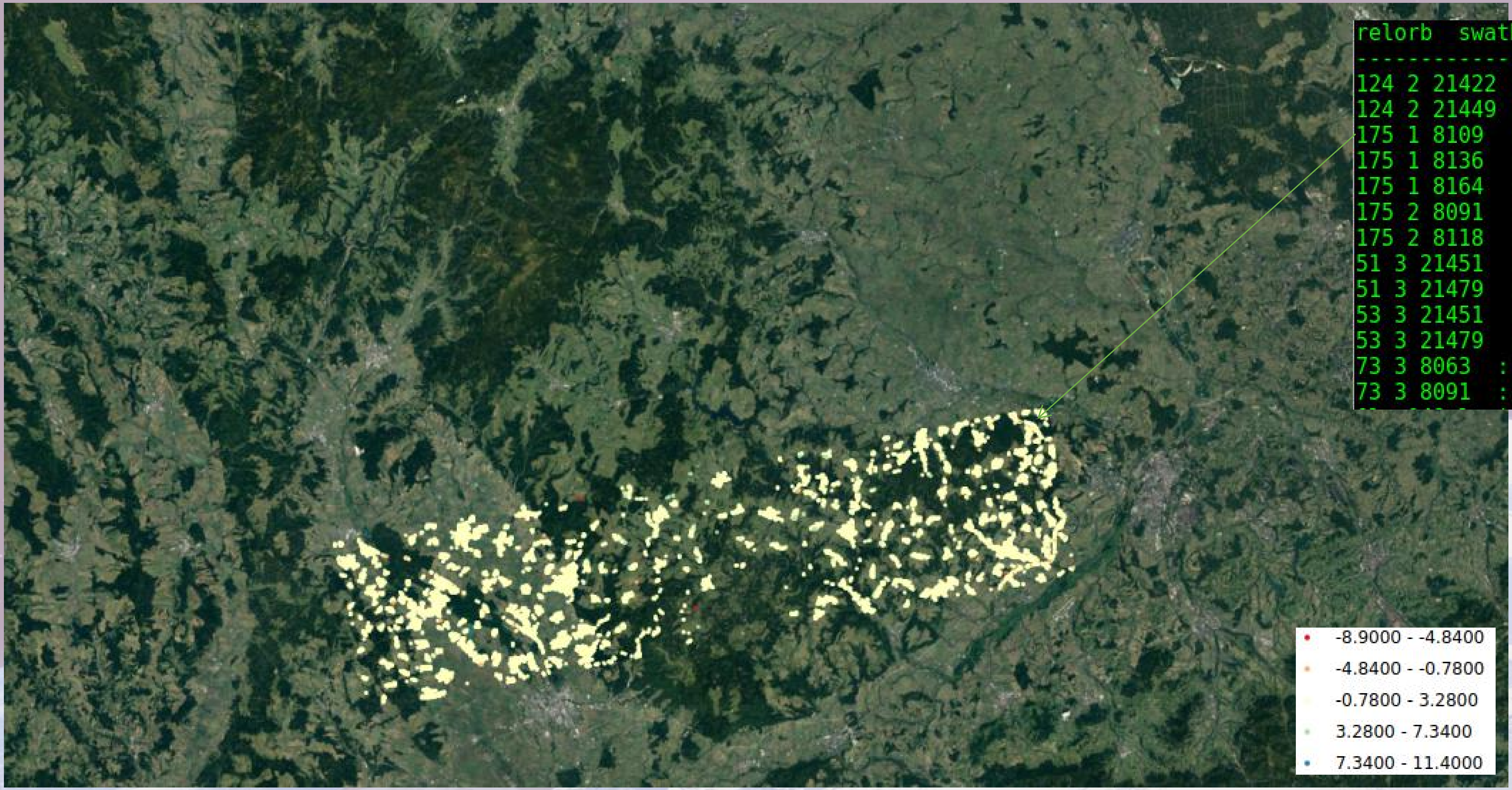



```
relorb  swath  burstid  :  imageno
----------------------------------
124 2 21422  :  108
124 2 21449  :  108
175 1 8109  :  94
175 1 8136  :  93
175 1 8164  :  93
175 2 8091  :  83
175 2 8118  :  83
51 3 21451  :  82
51 3 21479  :  82
53 3 21451  :  0
53 3 21479  :  0
73 3 8063  :  4
73 3 8091  :  4
```

PS InSAR: ~2 h

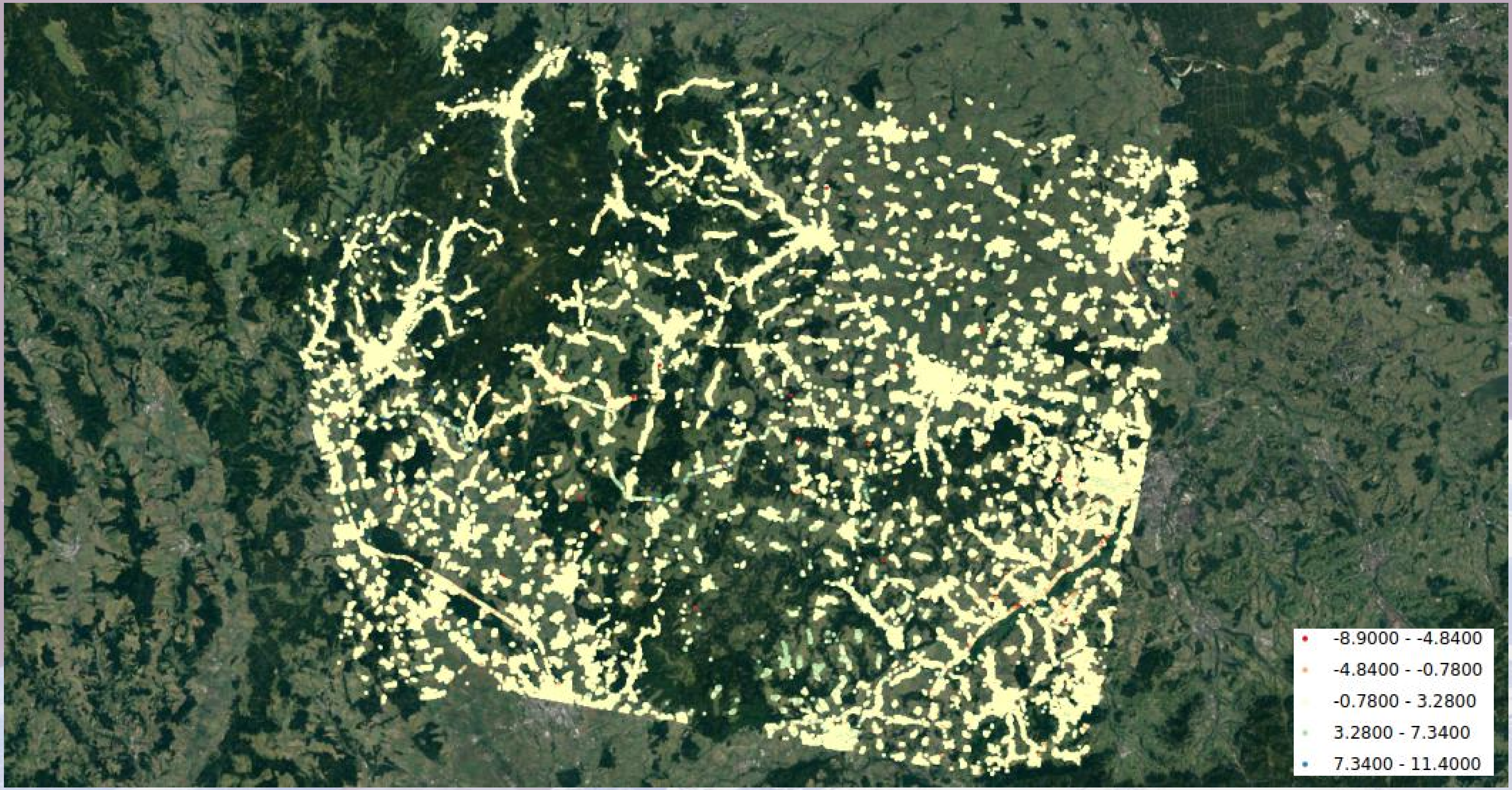
IT4S1 - first results

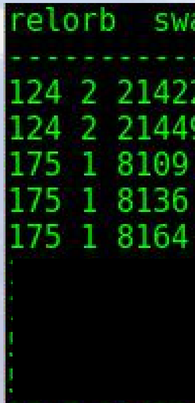
relorb	swath	burstid	:	imageno
124	2	21422	:	108
124	2	21449	:	108
175	1	8109	:	94
175	1	8136	:	93
175	1	8164	:	93
175	2	8091	:	83
175	2	8118	:	83
51	3	21451	:	82
51	3	21479	:	82
53	3	21451	:	0
53	3	21479	:	0
73	3	8063	:	4
73	3	8091	:	4



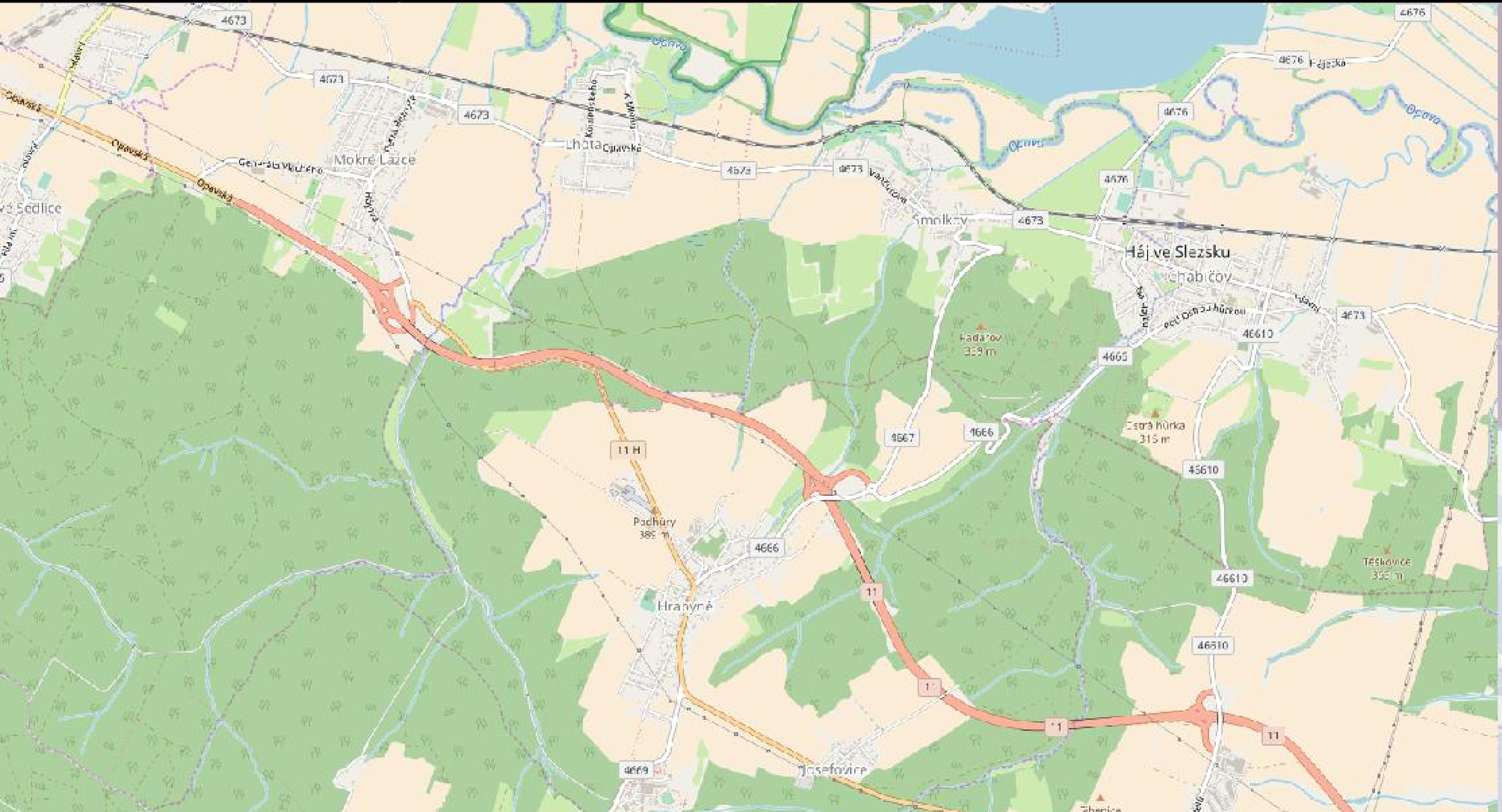
PS InSAR: 40 min.

IT4S1 - first results

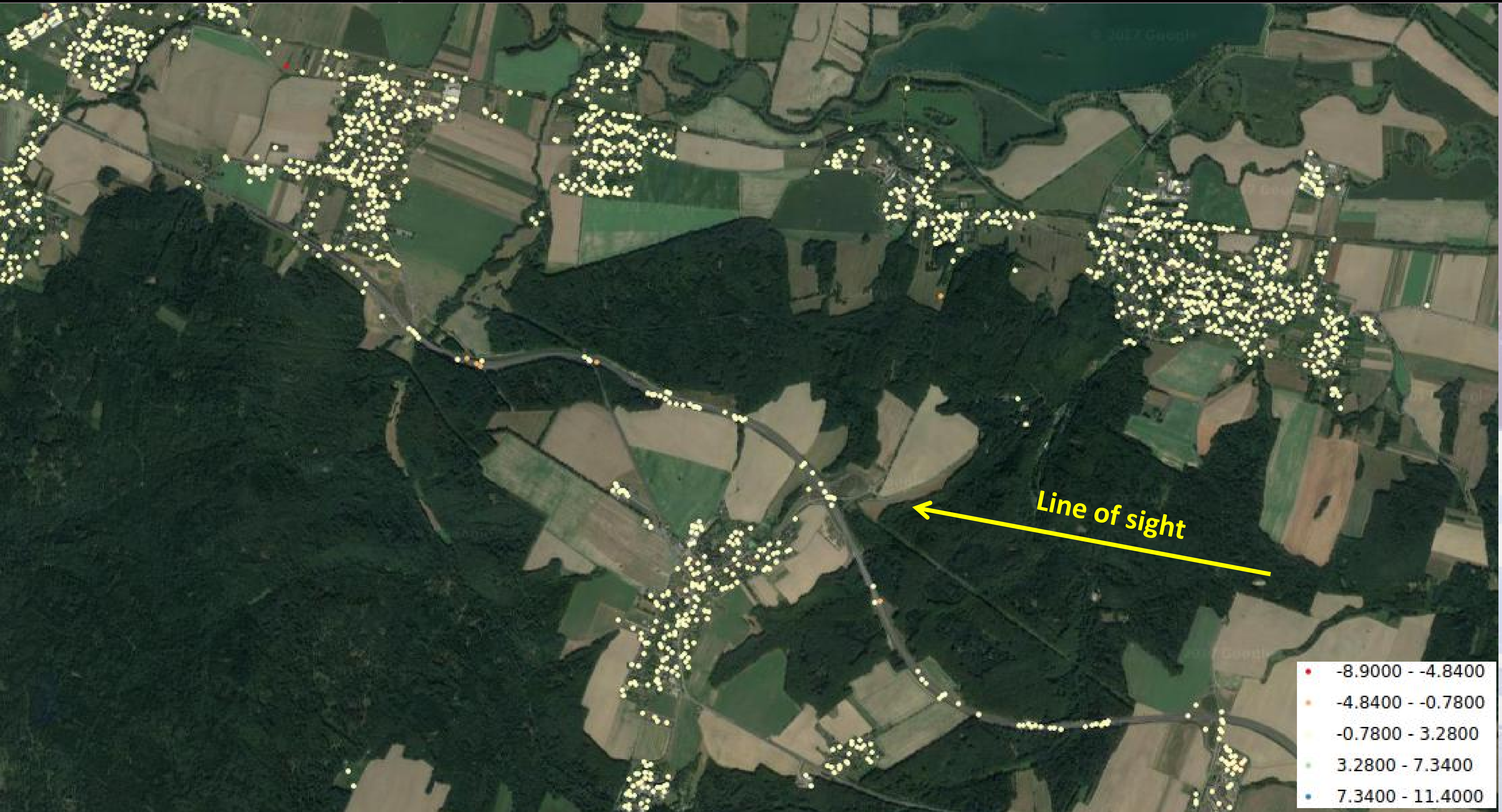




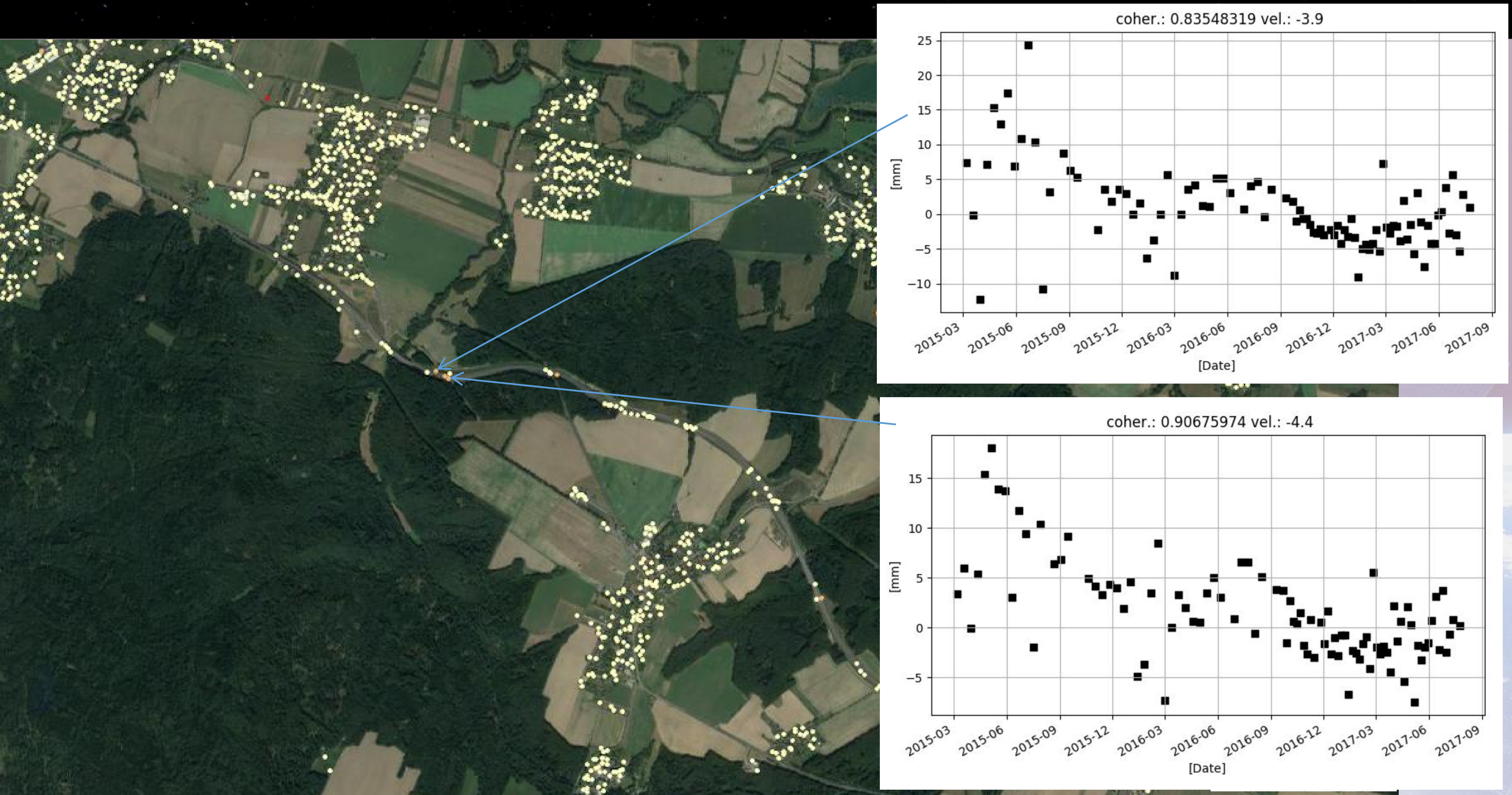
IT4S1 - first results



IT4S1 - first results

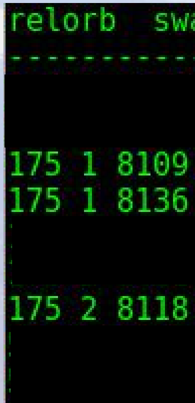


IT4S1 - first results

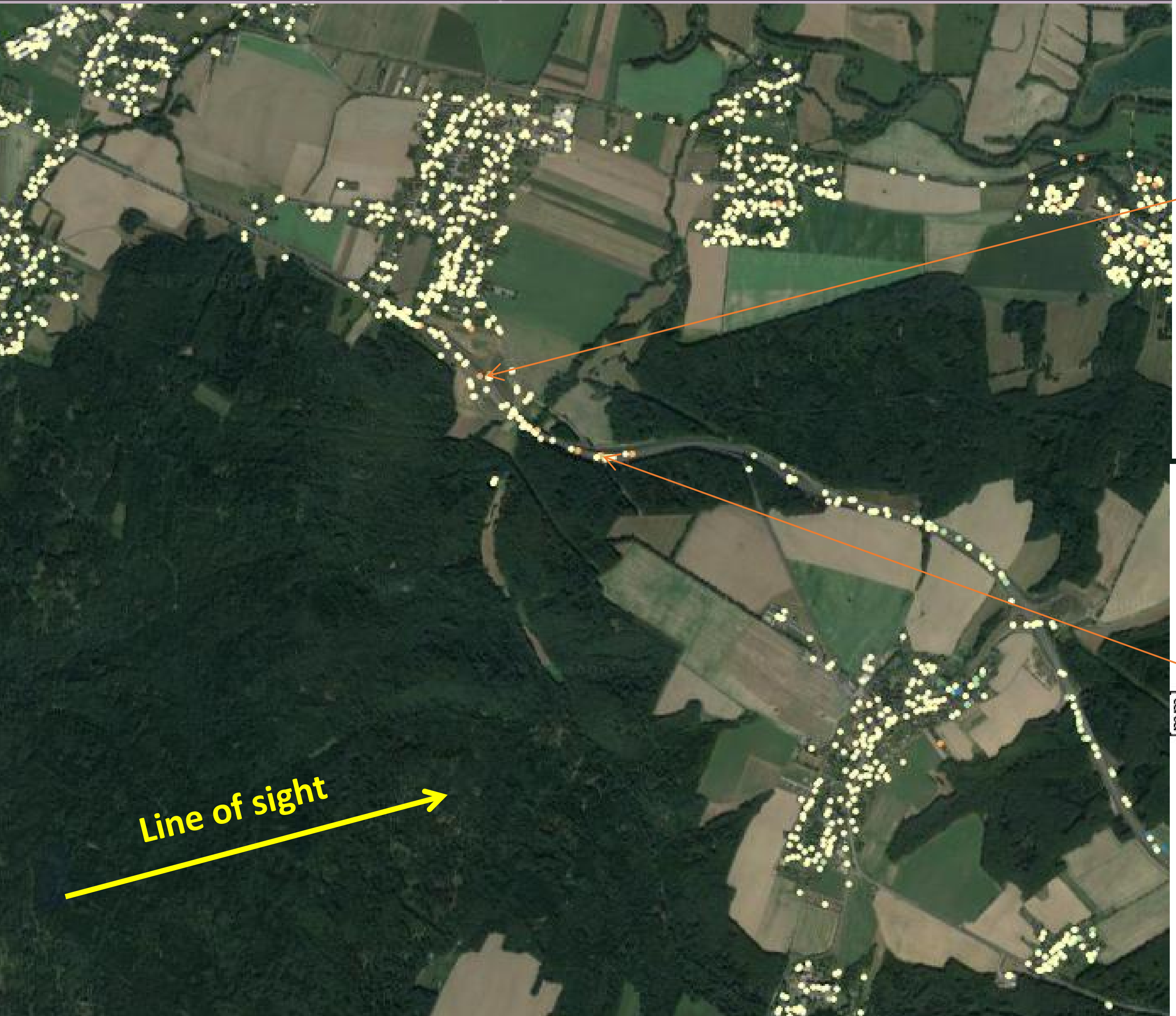


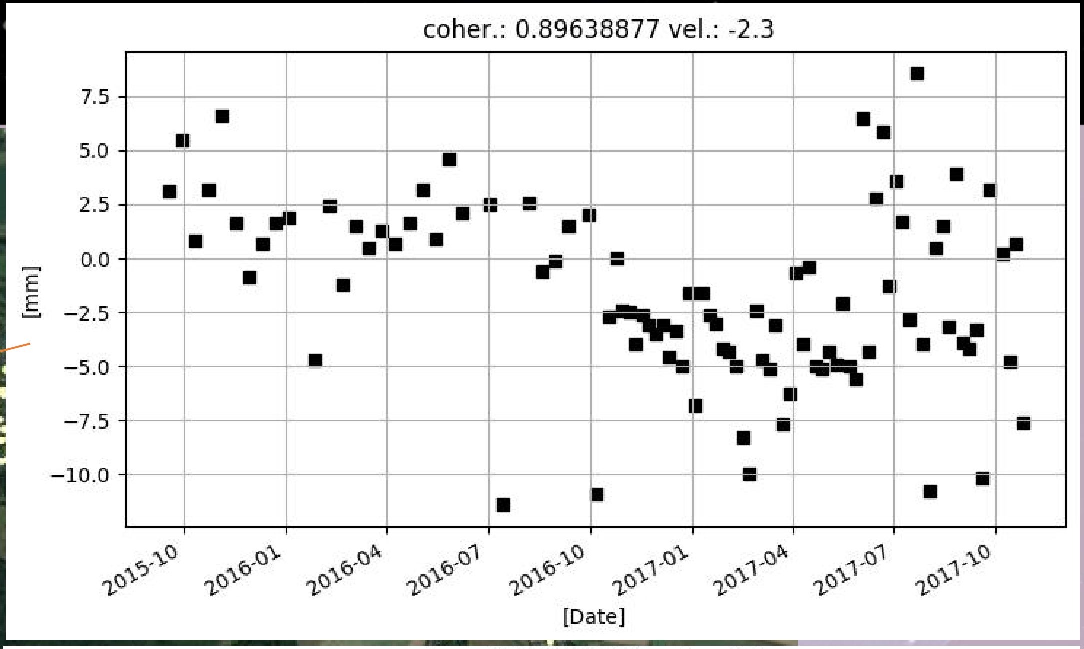
IT4S1 - first results

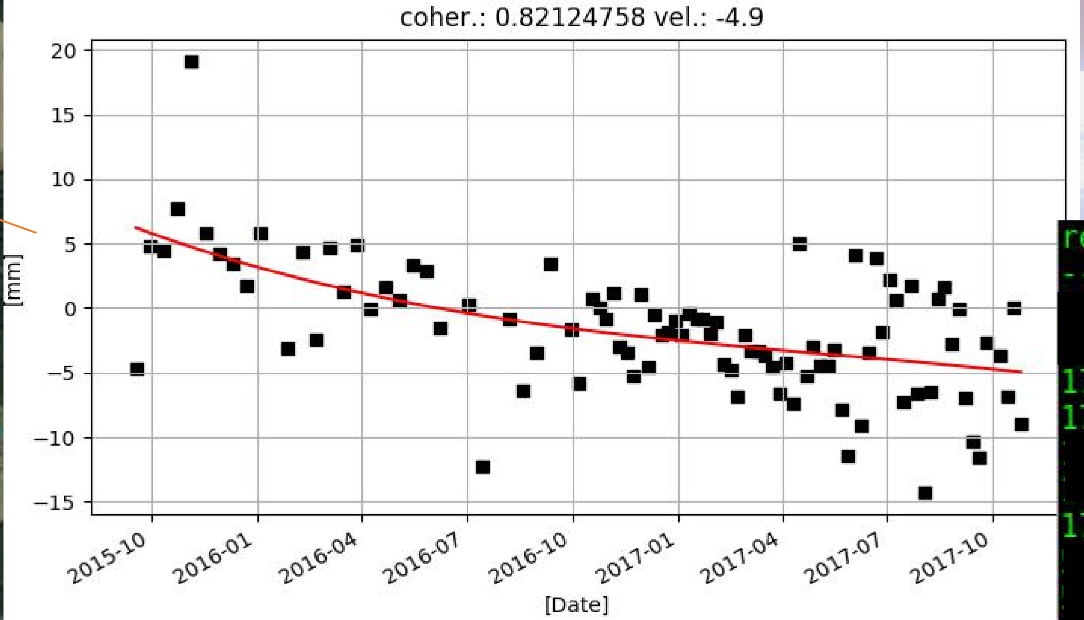
8109+8136+8118



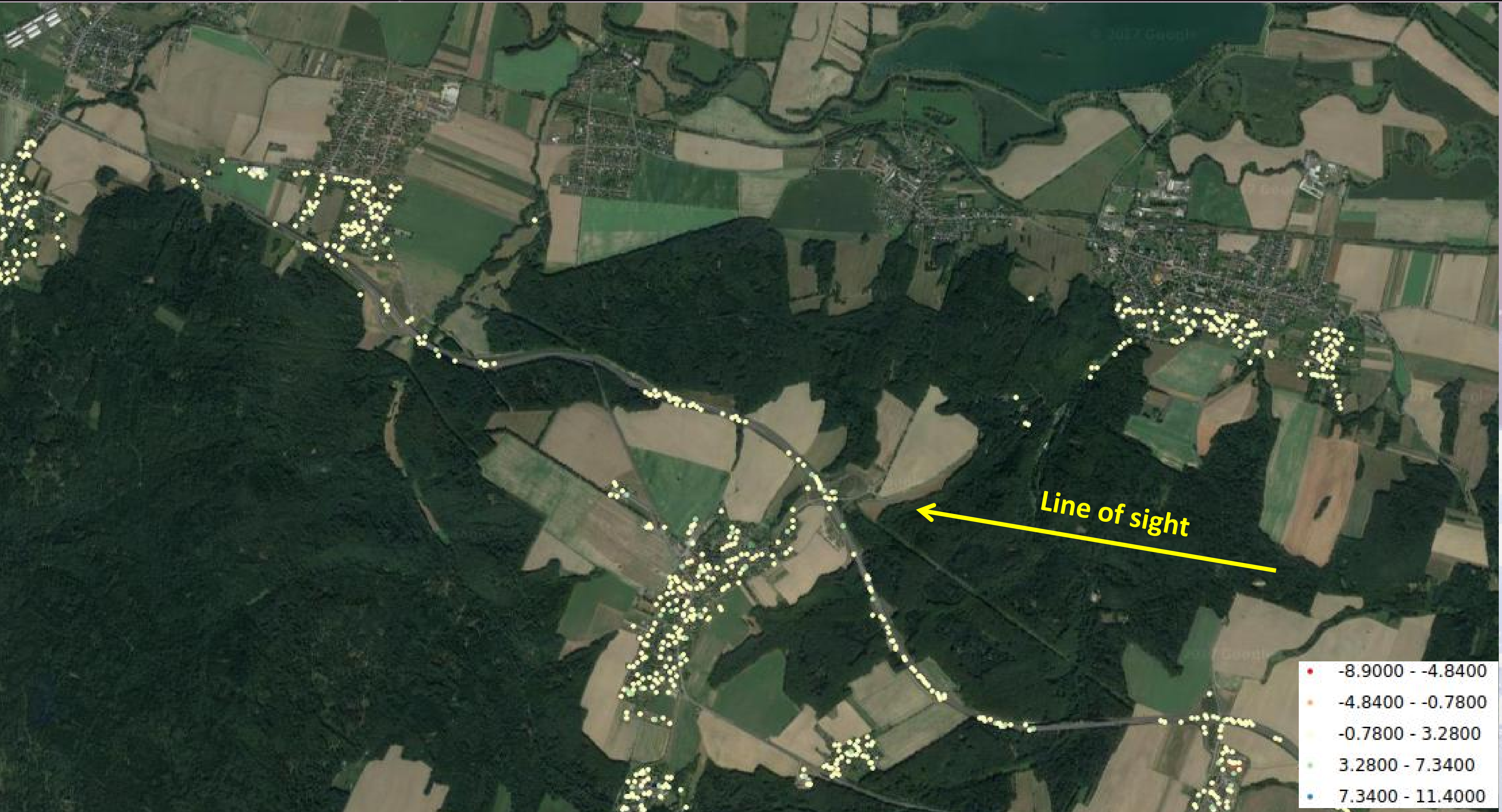
IT4S1 - first results



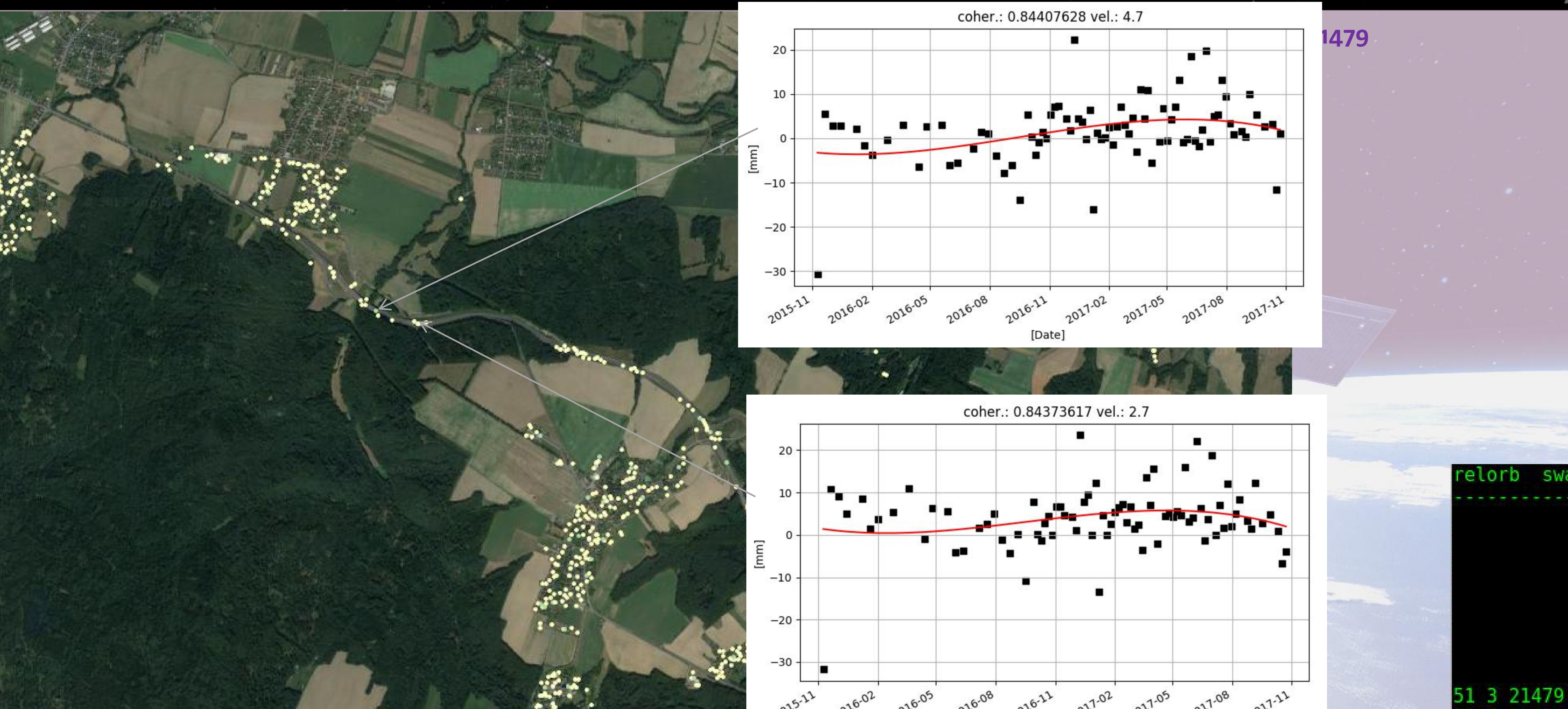




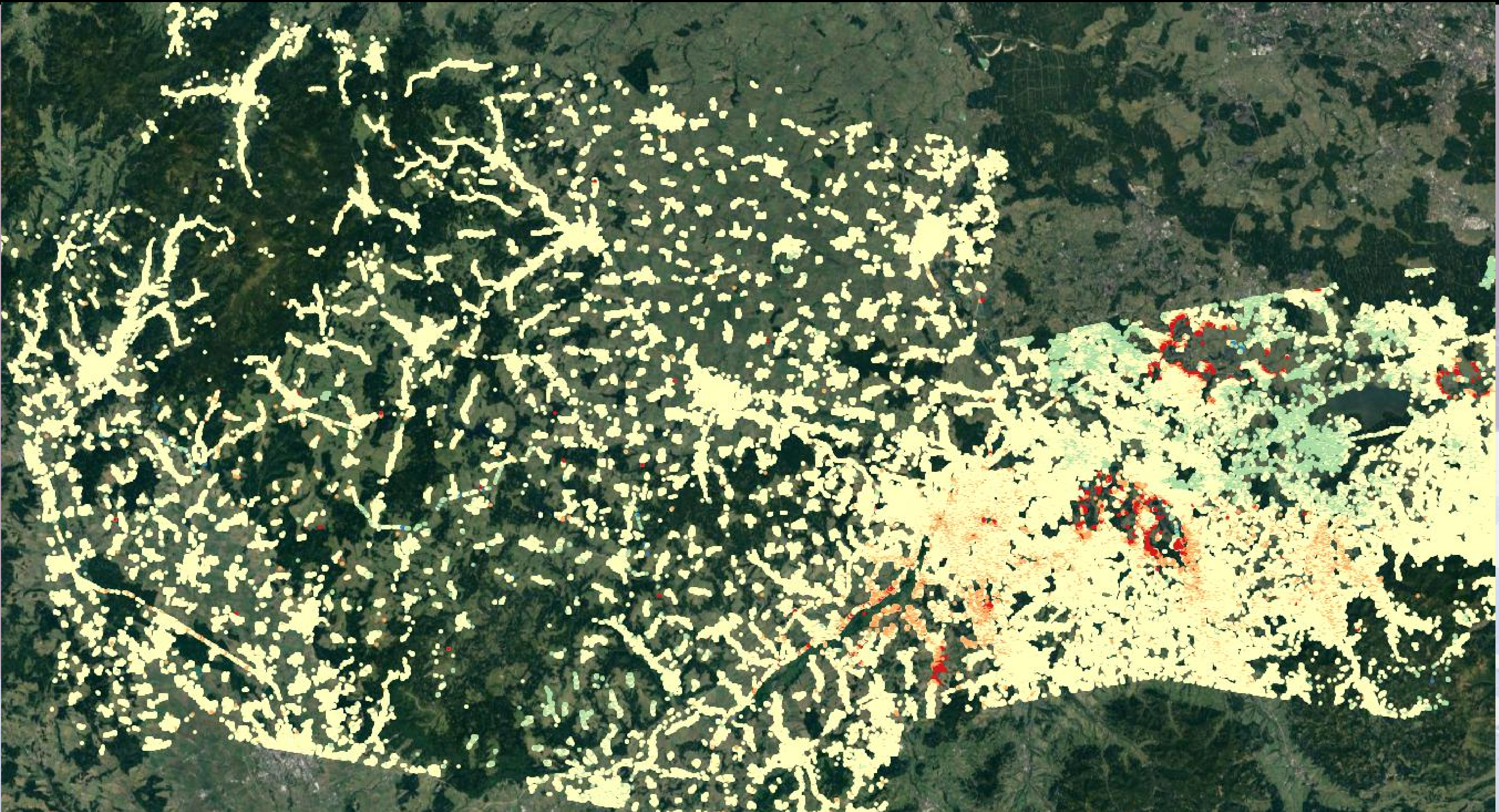
IT4S1 - first results



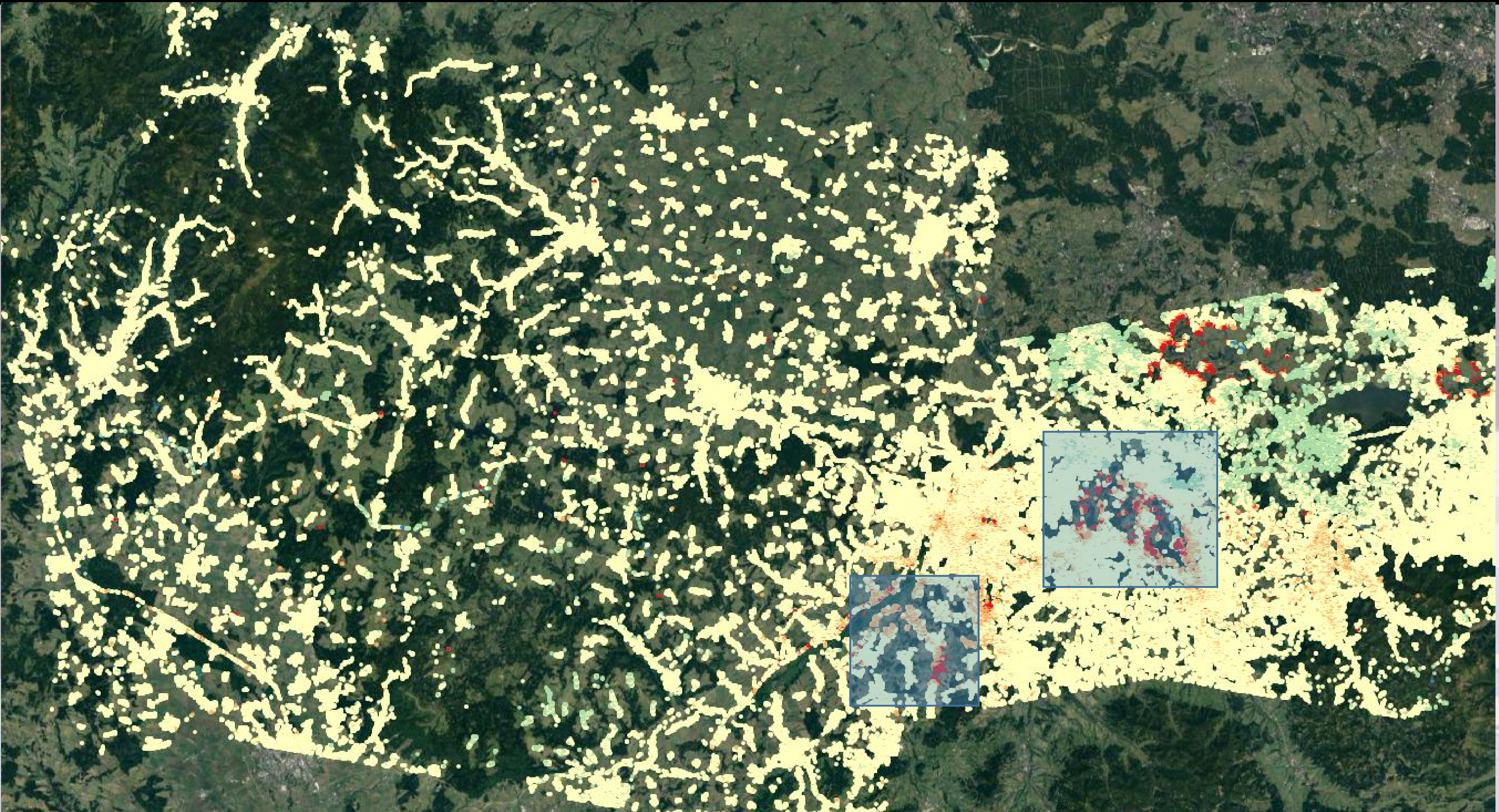
IT4S1 - first results



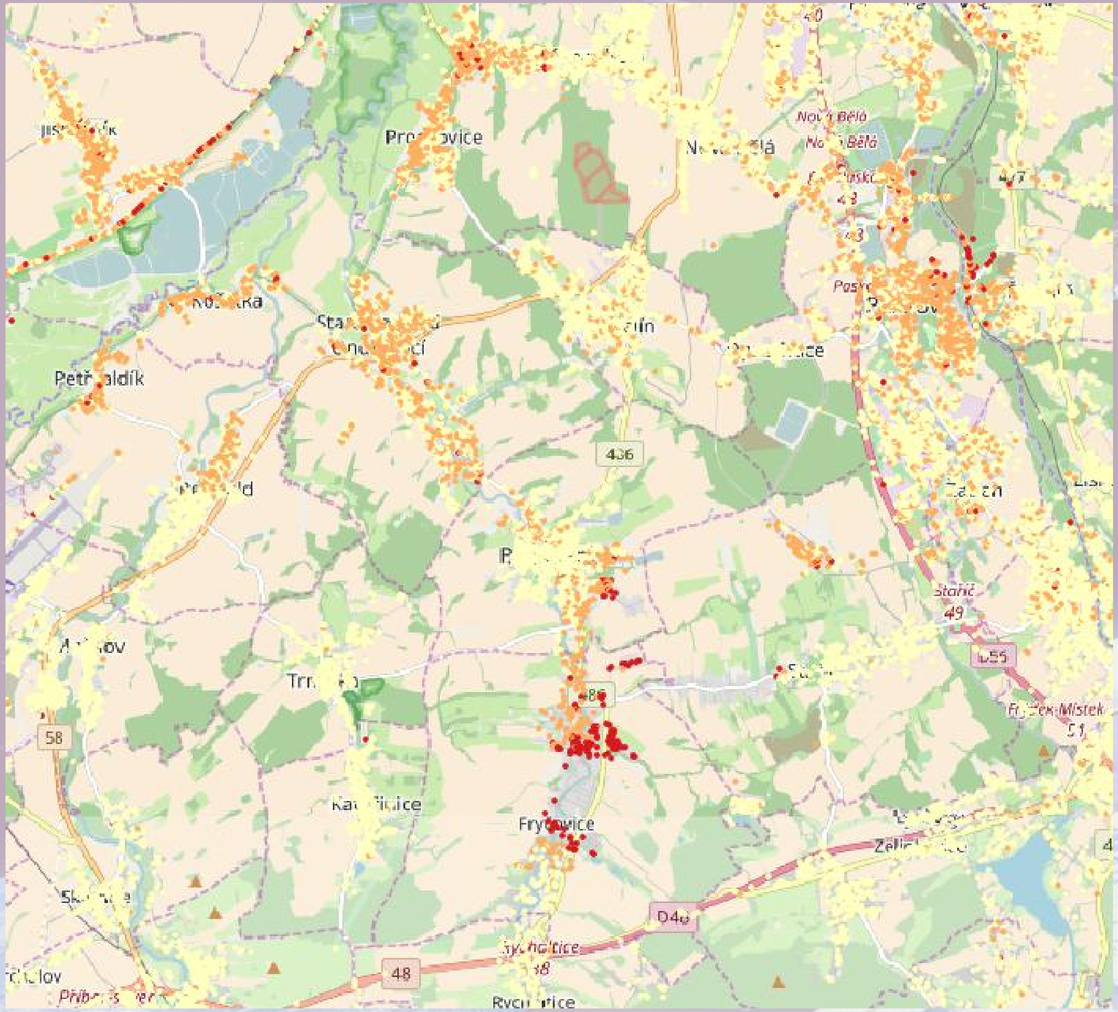
IT4S1 - first results - zoom out + new frames

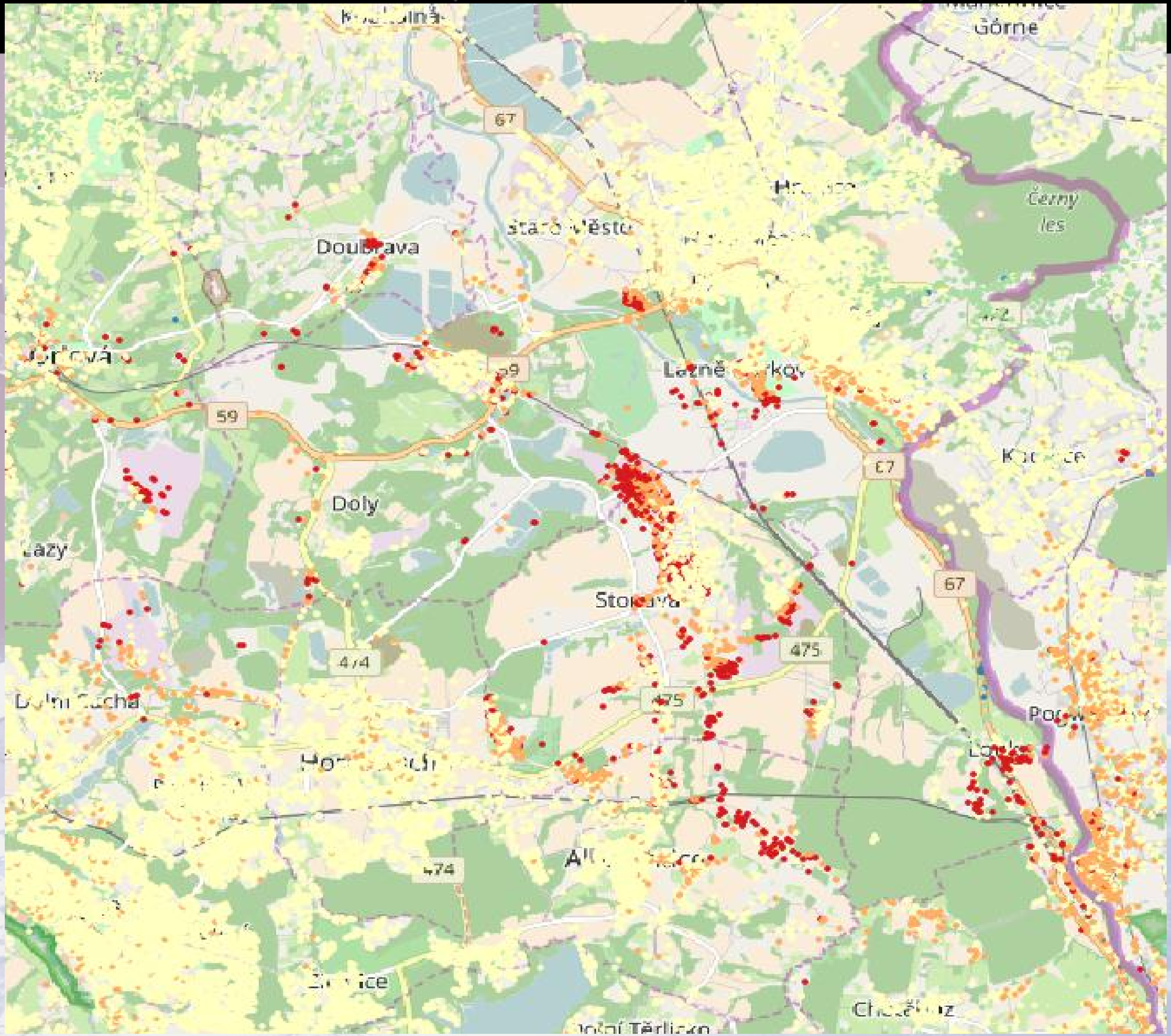


IT4S1 - first results - zoom out + new frames



IT4S1 - first results - zoom out + new frames



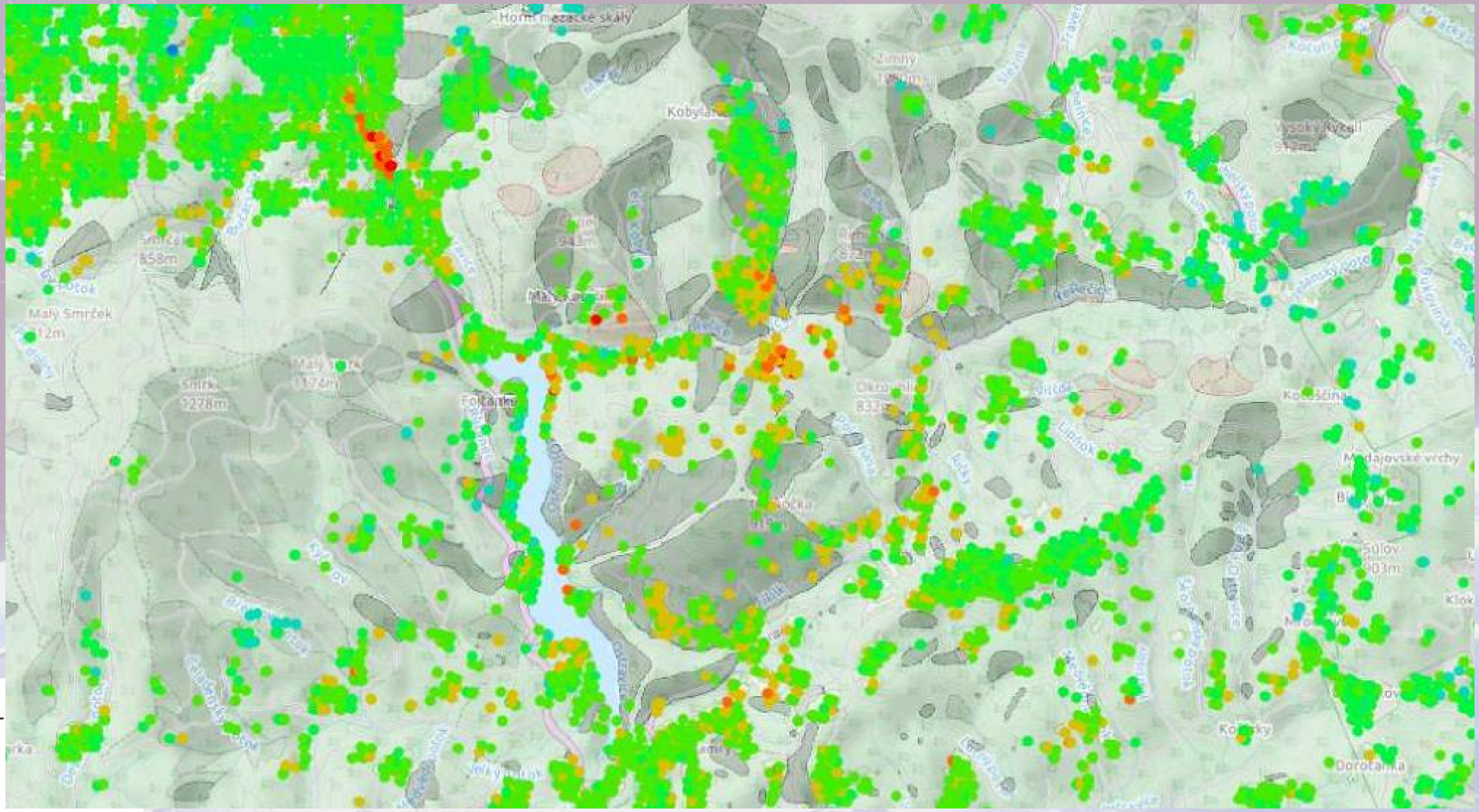


Further works for IT4S1

- improvements of codes
- application of partially prepared (post)processing scripts
  - decomposition, landslide identification,..
- preparing full pre-processing chain:
  - CZ: 8 tracks per ~120 images x 24 corehours = 23040 c.hours = ~1 core-month
- calibration of intensity images for dual-polarization processing
- include external information (weather, temperature, landuse?)
- include other techniques for full exploitation (e.g. pixel offset tracking)
- inclusion of commercially available processing tools (?)

Expectations for IT4S1

- full national map of potential landslide activity



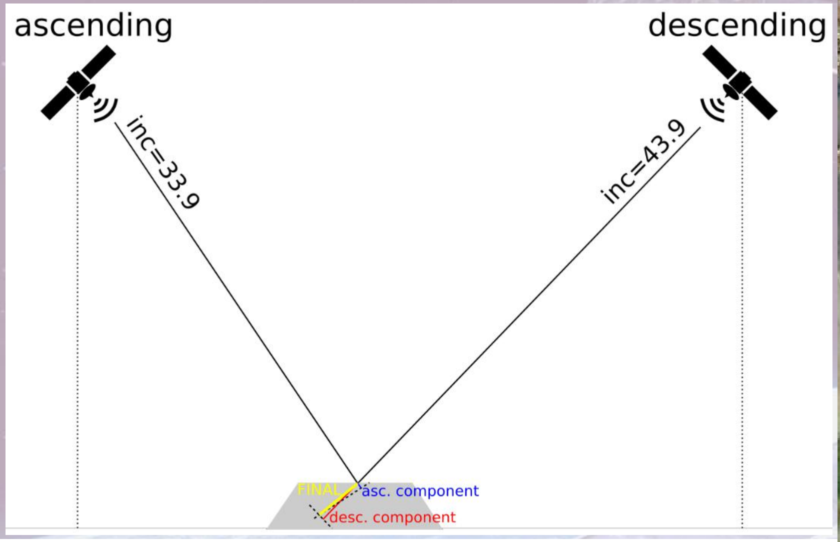
The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL
XXIII ISPRS Congress, 12–19 July 2016, Prague, Czech Republic

POTENTIAL OF SENTINEL-1A FOR NATION-WIDE ROUTINE UPDATES OF ACTIVE LANDSLIDE MAPS

M. Lazecky [a]* F. Canaslan Comut [b], E. Nikolaeva[c], M. Bakon[d] , J. Papco[d], A. M. Ruiz-Armenteros[e], Y. Qin[f], J. J. M. de Sousa[g], P. Ondrejka[h]

Expectations for IT4S1

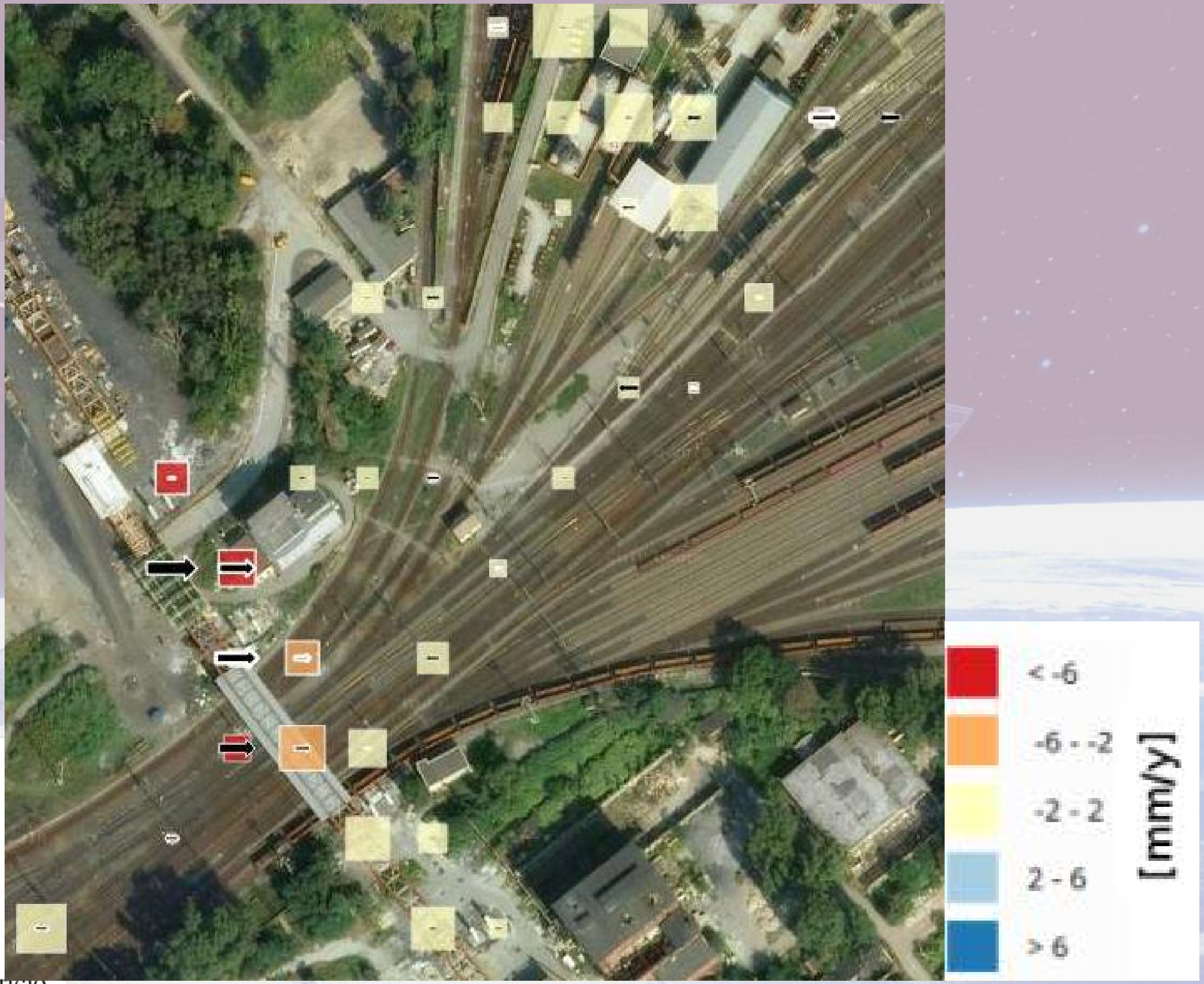
- map of decomposed displacements of infrastructure



IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING

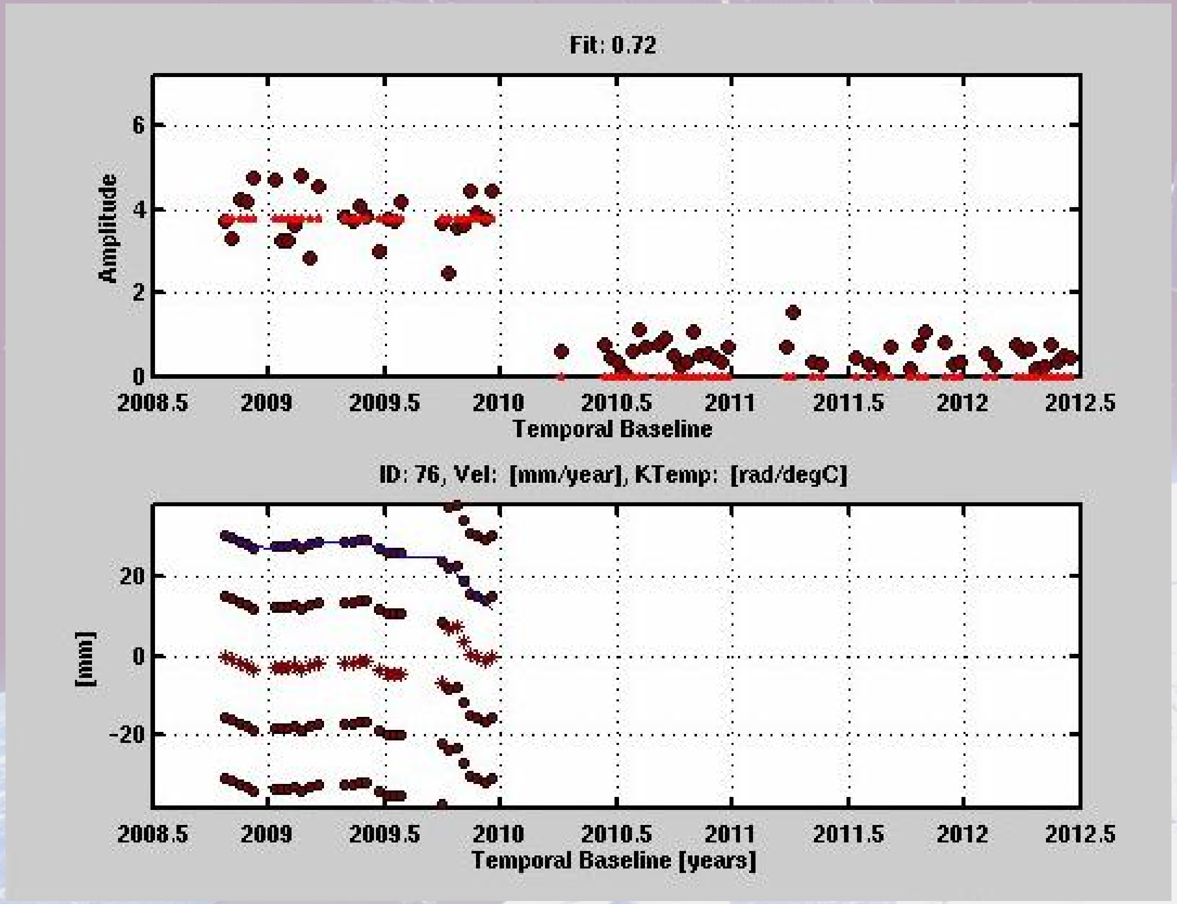
Bridge Displacements Monitoring Using Space-Borne X-Band SAR Interferometry

Milan Lazecky, Ivana Hlavacova, Matus Bakon, Joaquim J. Sousa, Daniele Perissin, and Gloria Patricio



Expectations for IT4S1

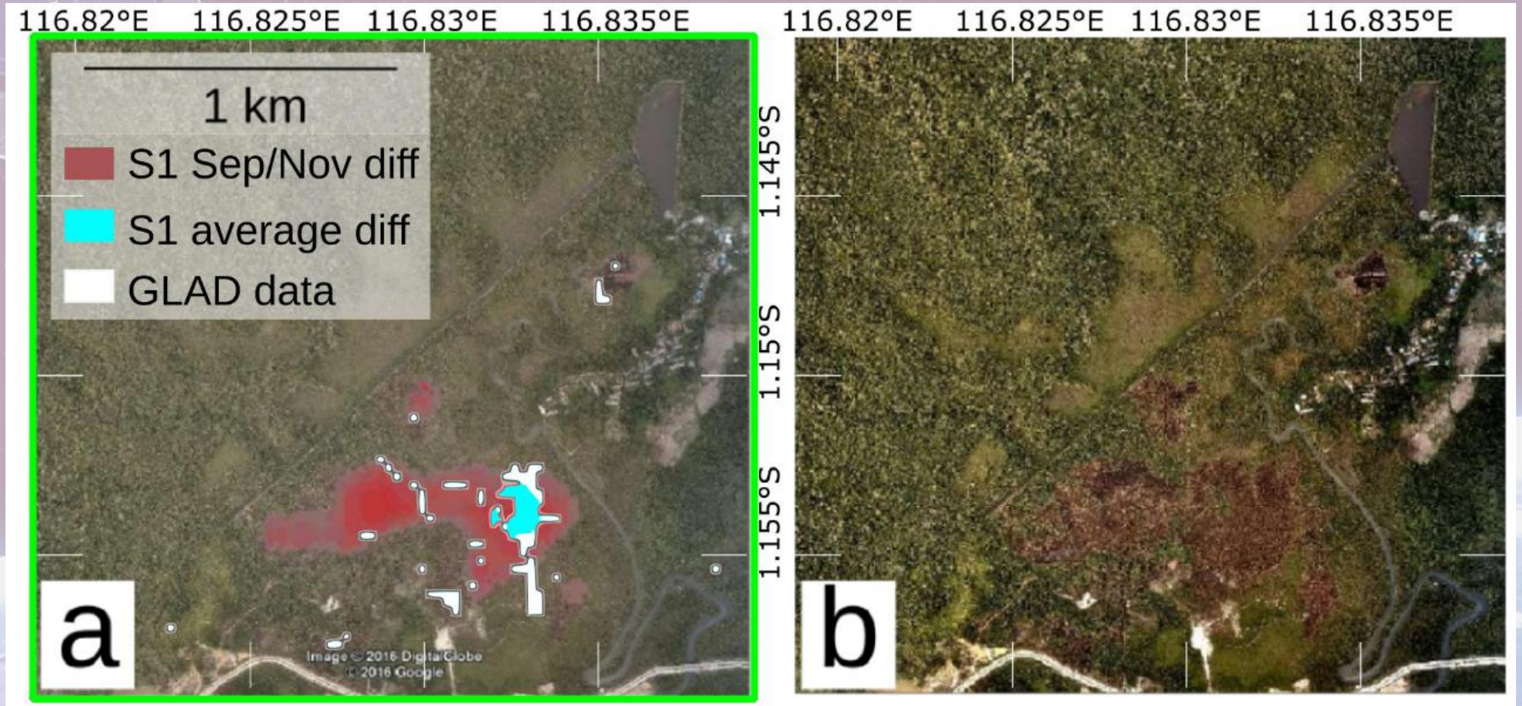
- early warning about structure destabilization



Hong–Kong building collapse
(29th January 2010)

Expectations for IT4S1

- identification of deforestation and other (semi-)automatic outputs



EVALUATION OF FOREST LOSS IN BALIKPAPAN BAY IN THE END OF 2015 BASED ON SENTINEL-1A POLARIMETRIC ANALYSIS

MILAN LAZECKÝ[1], STANISLAV LHOTA[2], ZUZANA POHANKOVÁ[2], PETRA WENGLARZYOVÁ[3], NEHA JOSHI[4]

Thank you for your attention