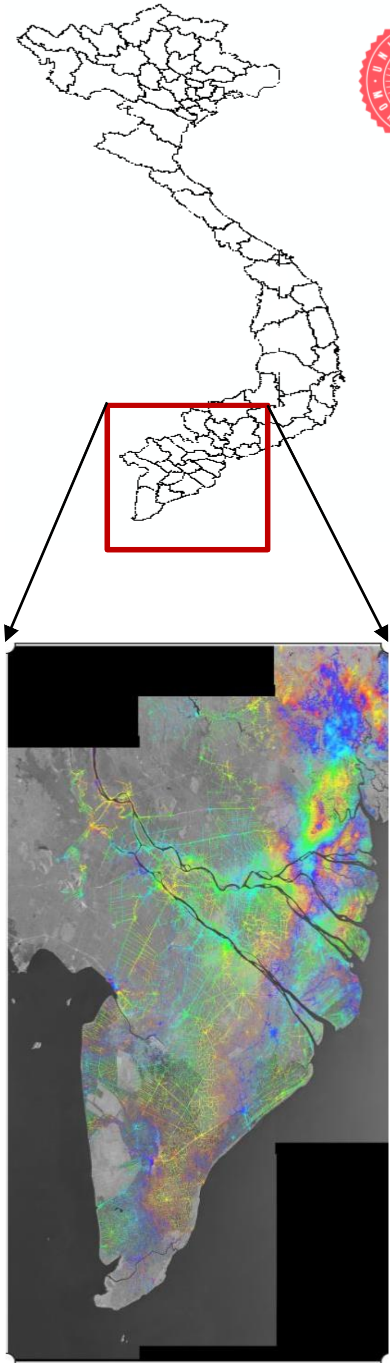

Sentinel-1 Interferometry SAR for large scale: Mekong Delta

Preliminary results

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La Petite-Pierre, October 2019

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From PS to PS+DS processing

<u>Summary of the SAR interferometric phase contributions</u>

PS pixels
small noises

$$\Delta\varphi = \Delta\varphi_{topo} + \Delta\varphi_{defo} + \Delta\varphi_{aps} + \Delta\varphi_{noise}$$

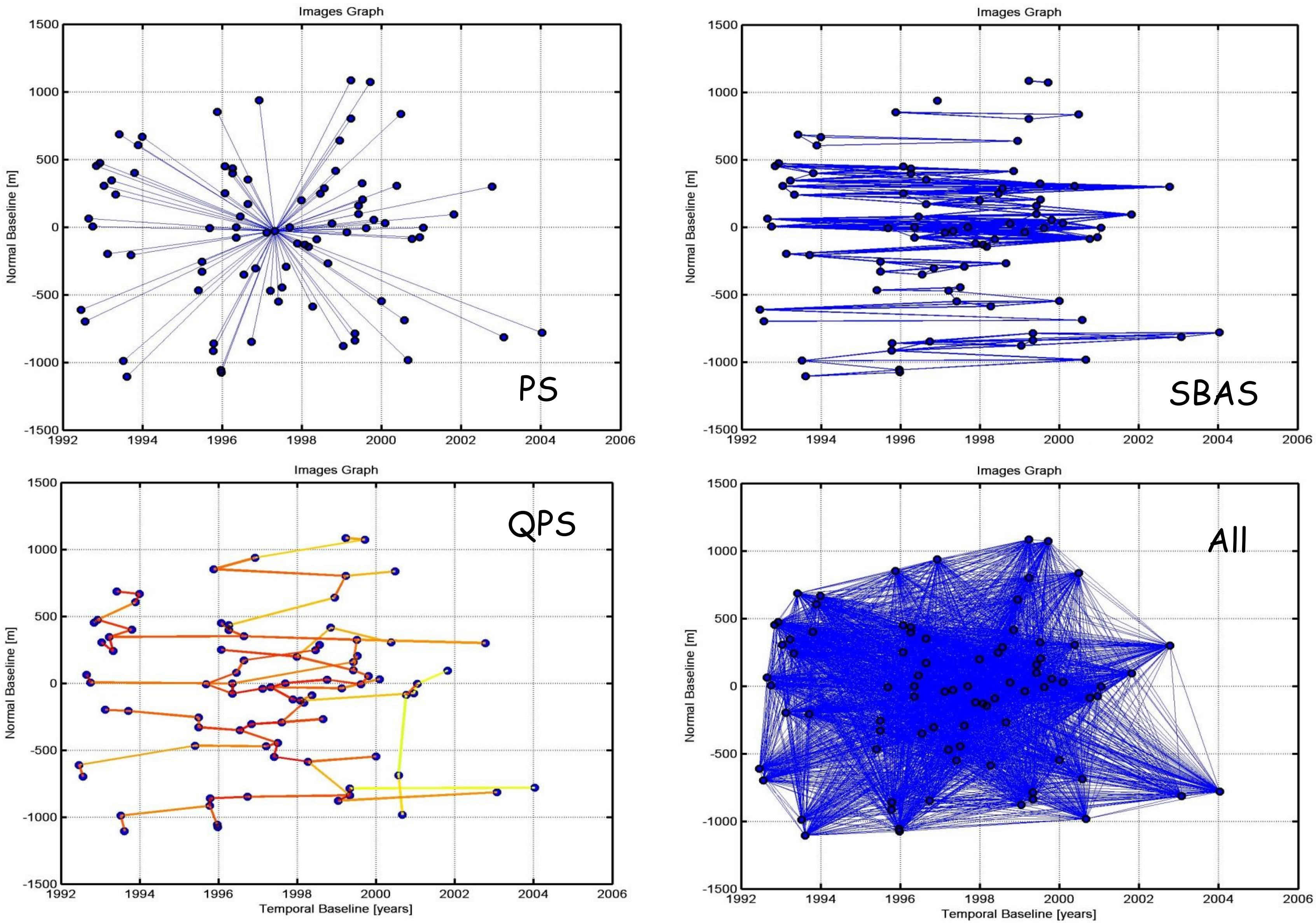
$$\boxed{\frac{\Delta h}{\sin\theta} \cdot \frac{B_n}{R_n} \cdot \frac{4\pi}{\lambda}} \qquad \boxed{\frac{4\pi}{\lambda} d}$$

Key idea: Instead of analyzing the entire images, the analysis is based only on the selection of a number of highly coherent (Permanent/Persistent Scatterers - PS), temporally stable, point-like targets within the imaged scene.

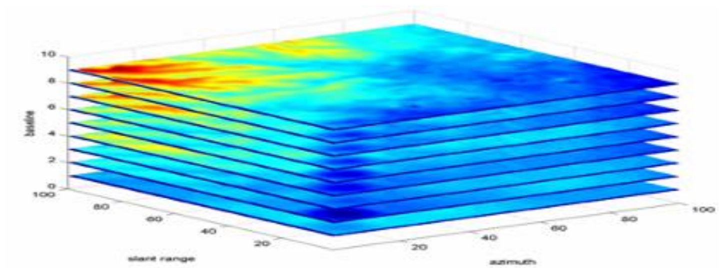
- <u>Systematic analysis</u> of InSAR data taking advantage of the available data set.
- <u>Estimation and removal</u> of the Atmospheric Phase Screen (APS).
- <u>Extraction</u> of the phase contribution due to target motion with high accuracy.

➢**Beyond PS**: We want to use both deterministic (point-wise - PS) and stochastic (distributed - DS) targets. To detect DS, we adopt a statistical test to identify Statistically Homogeneous Pixels (SHP) in the neighborhood of each pixel.

Possible interferometric sets

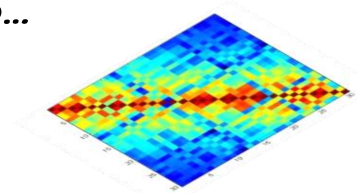


PS+DS approach



Find SHP

➔ for each DS…



From N/(N-1)/2 itfgs…

via Phase linking

$[\,\Phi_0\ \Phi_1\ \ \Phi_2\ \ \Phi_3\ ....\ \Phi_{N-1}\,]$

..to N-1 optimum phase values..

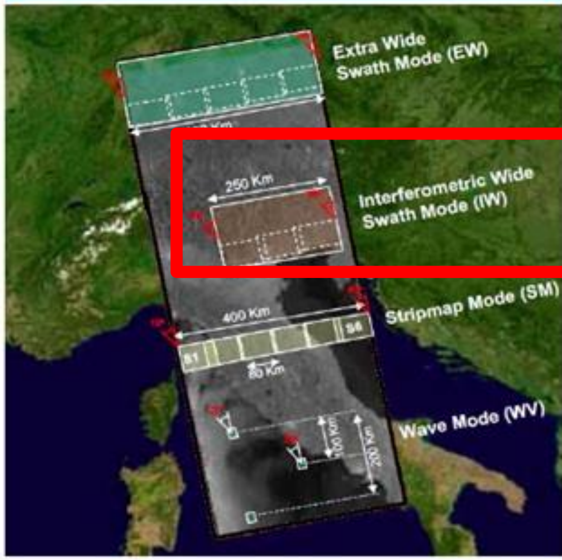
3D Phase Unwrapping

Displacement Estimation

Ferretti et al. *"A New Algorithm for Processing Interferometric Data-Stacks: SqueeSAR"*

Sentinel-1

Operational Modes



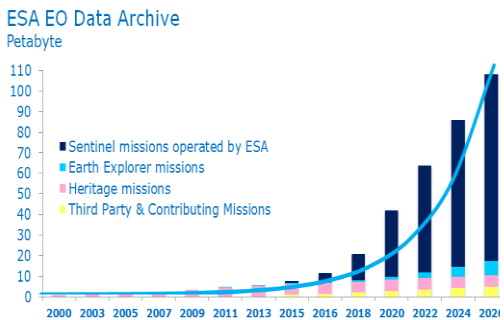
Resolution	Swath Width	Polarisation
20 x 40 m²	> 400 km	HH+HV or VV+VH
5 x 20 m²	> 250 km	HH+HV or VV+VH
5 x 5 m²	> 80 km	HH+HV or VV+VH
5 x 5 m²	20 x 20 km² at 100 km spacing	HH or VV

- **Daily coverage of high priority areas, e.g. Europe, Canada, shipping routes**

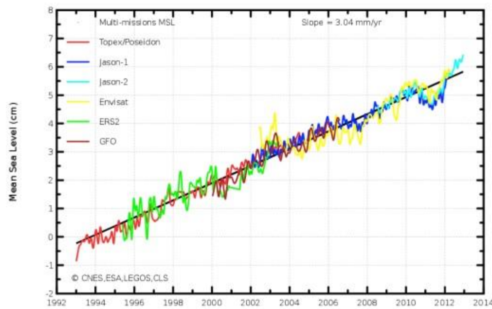
Main modes of operations:

- IW over land and coastal waters (normally VV or VV-VH polarization)
- EW over extended sea (VV or VV-VH) and sea-ice (HH or HH-HV) areas
- WV over open oceans

Big Data Challenges



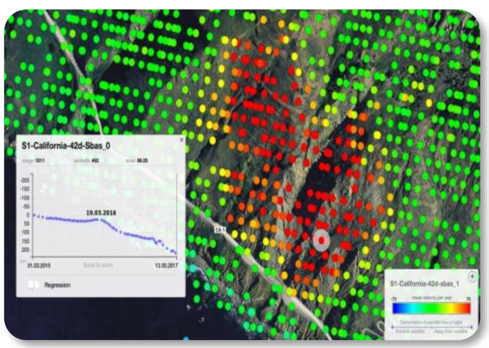
Data volume



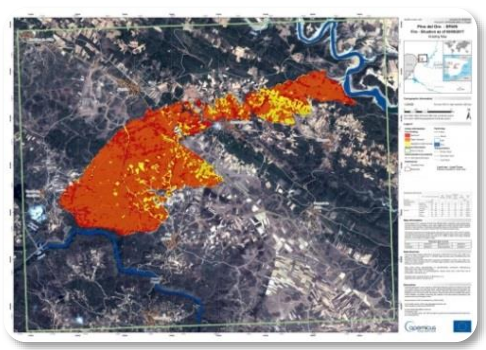
Data continuity

Data sharing

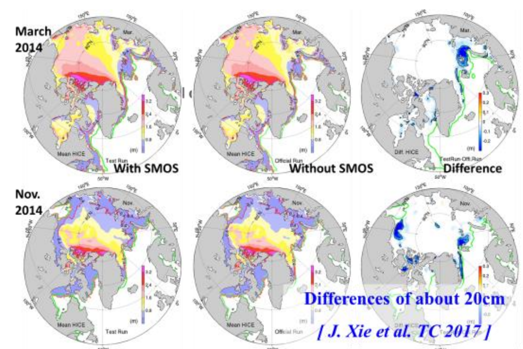
Data quality



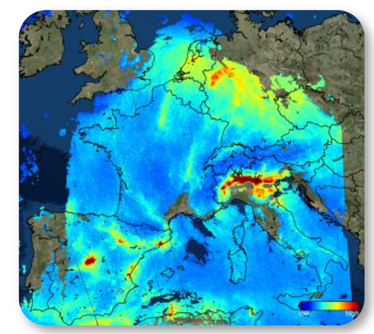
Innovation



Timeliness

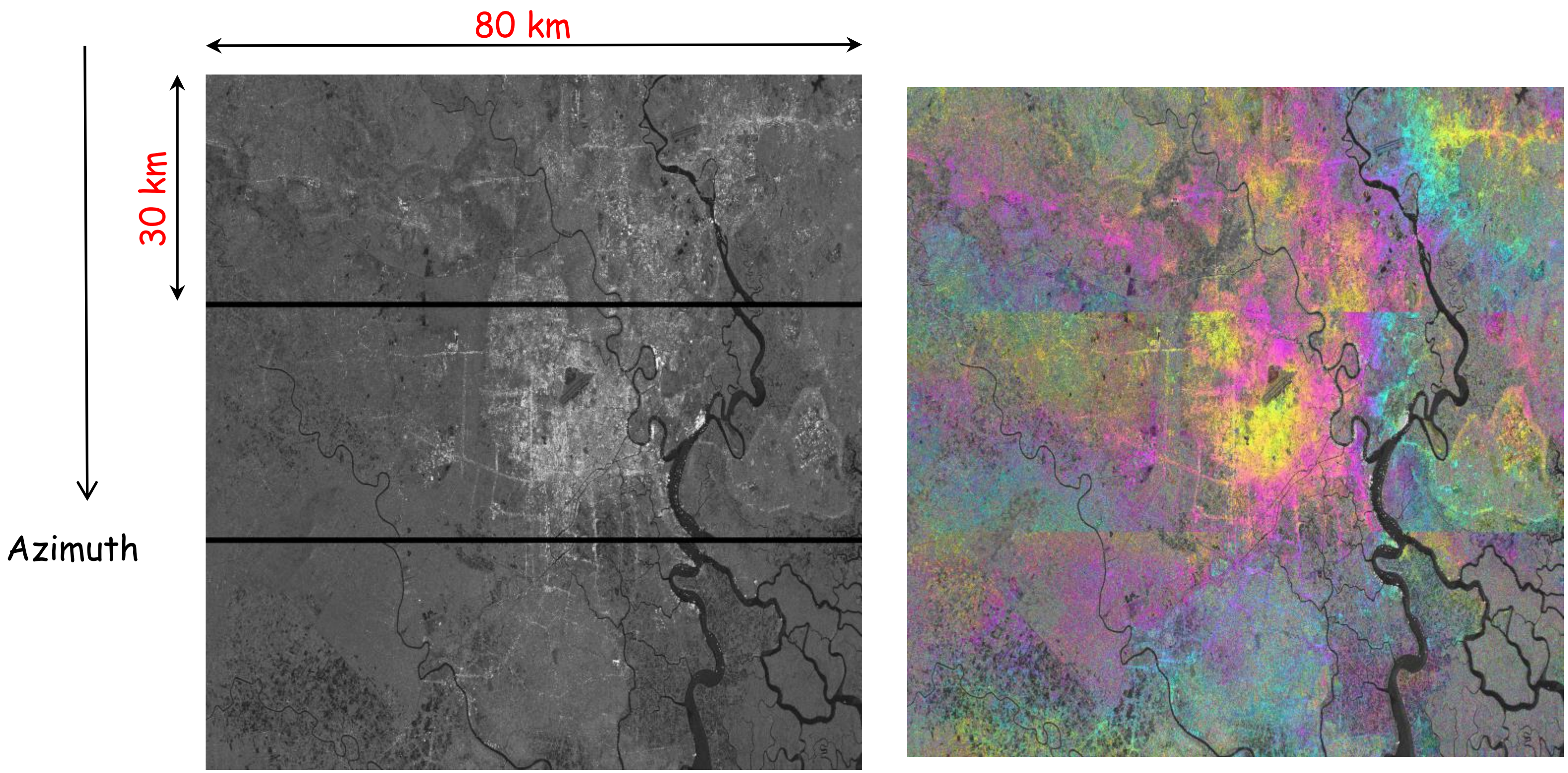


Mission synergies



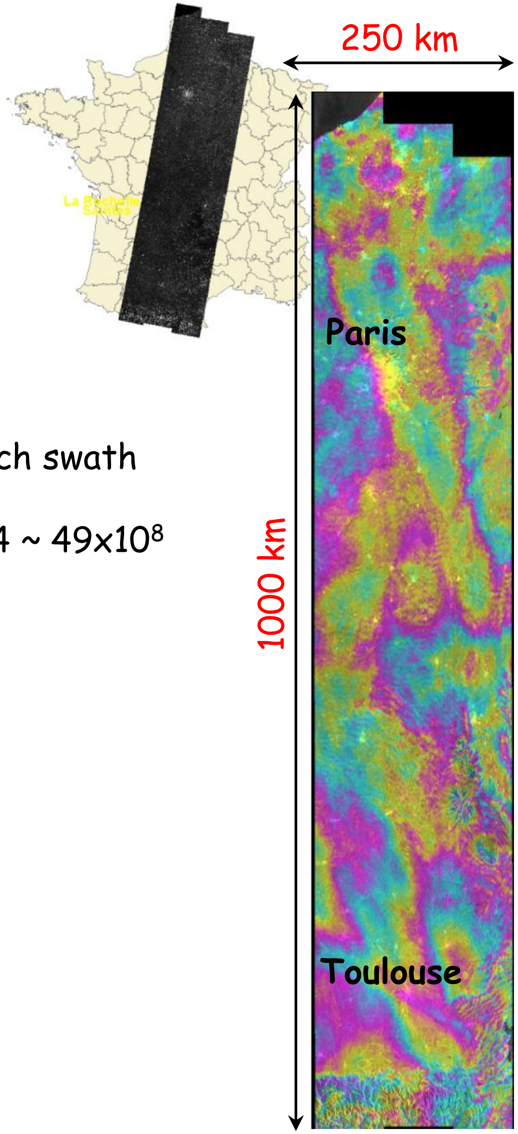
Uniqueness

TOPS Sentinel-1 interferometry



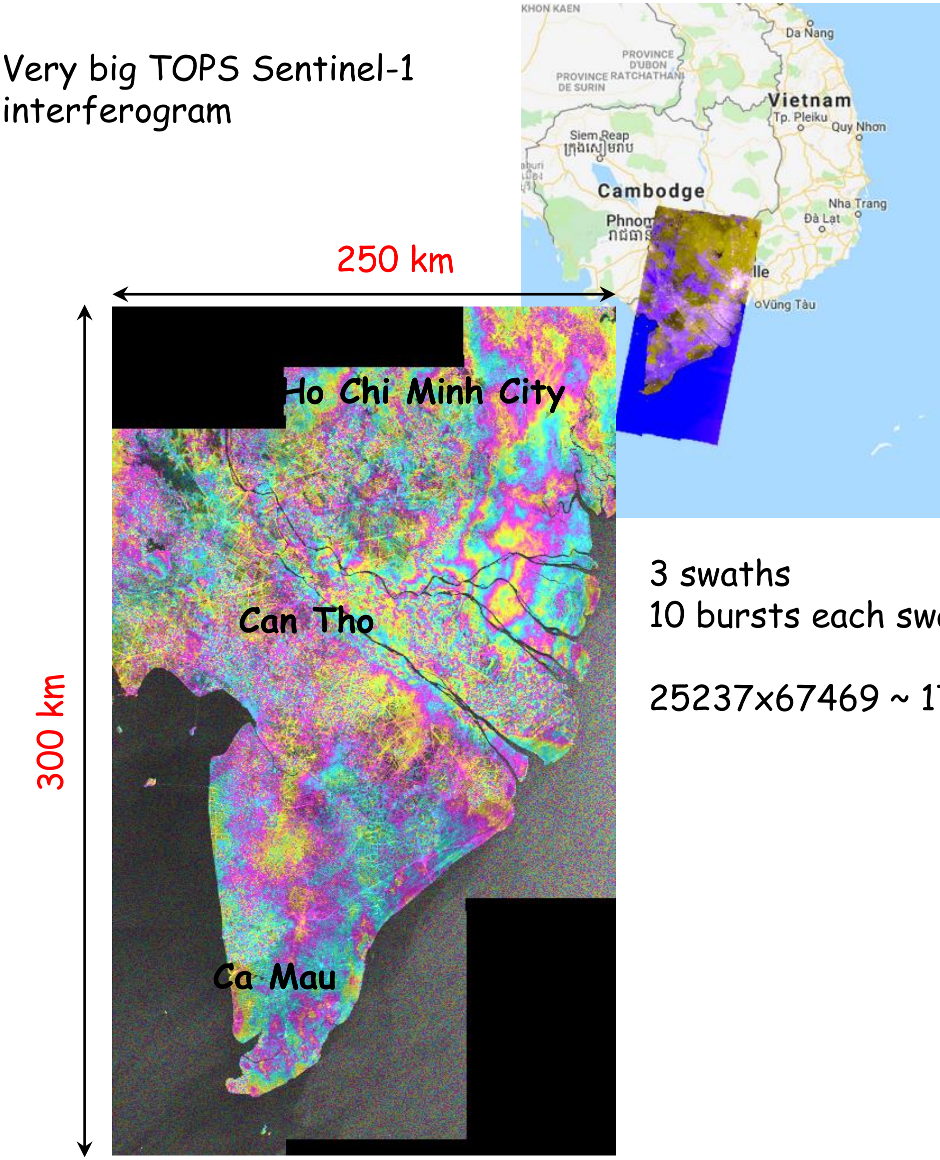
No really easy: TOPS Sentinel-1 phase is very sensitive to geometric errors. In case of a small misregistration (i.e., about 1.5 cm vs 15 m azimuth pixel size) error between a pair of images, this residual term leads to a phase jump in the interferometric phase. Due to this limitation, doing TOPS interferometry needs extremely high co-registration requirements (e.g., an accuracy of 0.001 pixel in azimuth direction) have to be met.

Very big TOPS Sentinel-1 interferogram



3 swaths
53 bursts each swath

$71705 \times 69714 \sim 49 \times 10^8$



3 swaths
10 bursts each swath

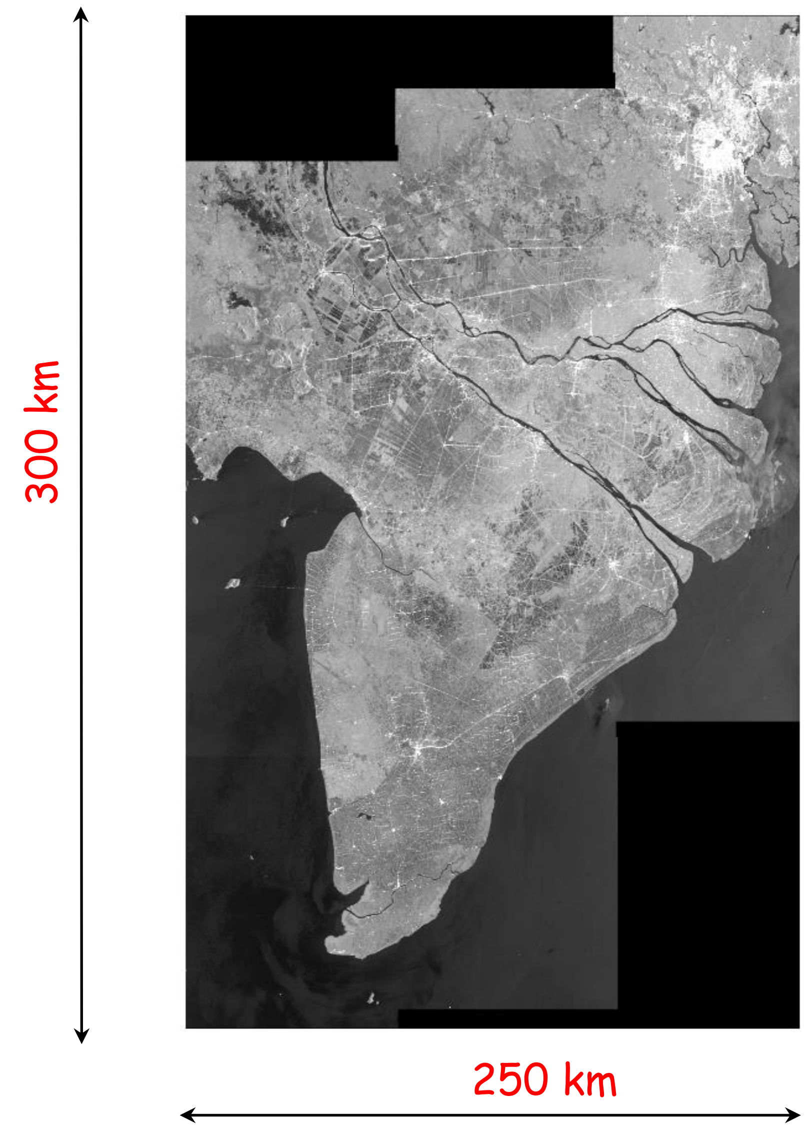
$25237 \times 67469 \sim 17 \times 10^8$

Processing: using 55 Sentinel-1 TOPS images from 2015-2019

yyyy-mm-dd

20150721
20150907
20151001
20151130
20151224
20160117
20160210
20160305
20160410
20160504
20160609
20160703
20160808
20160901
20161007
20161106
20161206
20170105
20170111
20170204
20170312
20170405
20170505
20170604
20170704
20170710
20170716
20170722
20170803
20170809
20170902
20171002
20171008
20171101
20171201
20171207
20180106
20180205
20180301
20180406
20180506
20180605
20180705
20180804
20180903
20181003
20181102
20181202
20190107
20190206
20190302
20190401
20190501
20190519
20190525

SAR intensity image



Many well-known time series InSAR processor available

Name	Year	Main code	Creator	Note	Support	APS removal
Gamma	1995	C	C. Werner	Commercial ($$$)	PS SBAS	Yes
TRE	1999	n/a	A. Ferretti	Service demand	PS PSDS	Yes
StaMPS	2005	Matlab	A. Hooper	Open source	PS SBAS	Limit – need TRAIN
SARSCAPE	200x	n/a	Sarmap	Commercial ($$)	PS SBAS	Yes
SARPROZ	2009	Matlab	D. Perissin	n/a	PS	Yes
NSBAS	2012	Fortran	M.-P. Doin et al.	Open source	SBAS	No need model
TomoSAR	2014	C	D. Ho Tong Minh and Y.-N. Ngo	Free service collaboration	PS SBAS PSDS	Yes
MintPy	2018	Python	F. Amelung et al.	Open source	SBAS	No need PyAPS

RAM consideration

3 swaths, 10 bursts each swath and 55 images: 55x25237x67469 ~ 55x 17×10^8

Original 55x 17×10^8 = 750 GB

(SLC float complex)

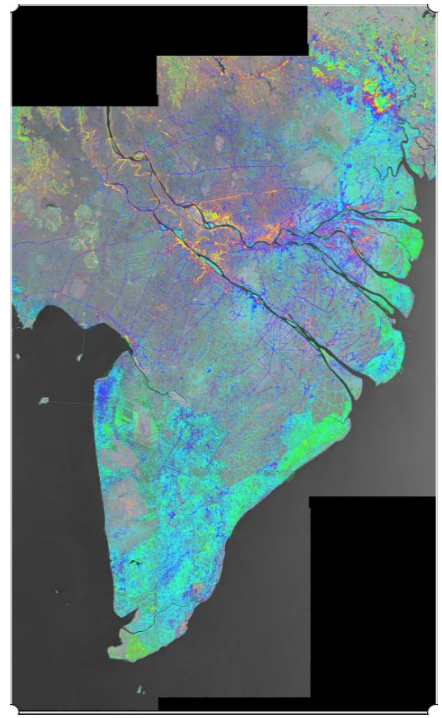
Consider PSDS (i.e., TomoSAR) scenario:

We extract signals at PSDS points.
We need three time memory to process signal.

Initial PSDS 3x 55x 14×10^6 = 18 GB

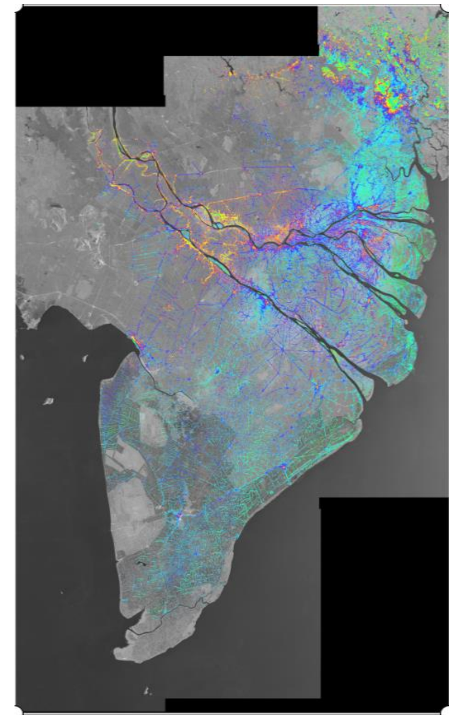
We are able to do if RAM > 18 GB.

Initial



14×10^6

Final PSDS



4.2×10^6

RAM consideration

3 swaths, 10 bursts each swath and 55 images: 55x25237x67469 ~ 55x 17×10^8

Original 55x 17×10^8 = 750 GB

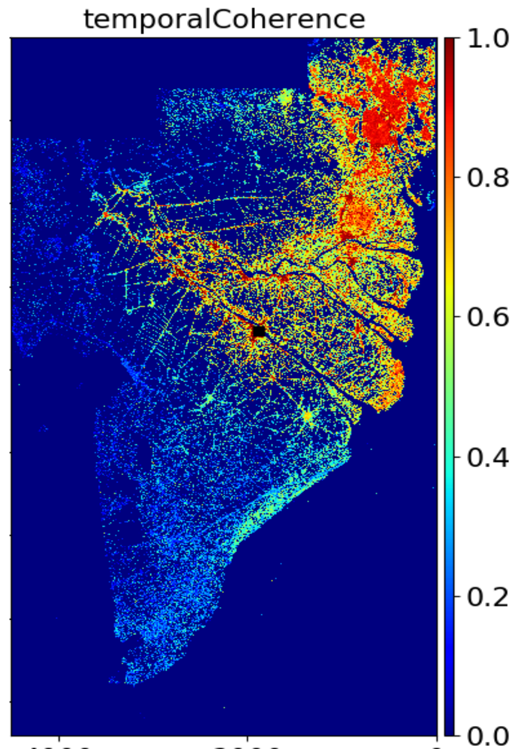
(SLC float complex)

Consider SBAS (i.e., MintPy) scenario:

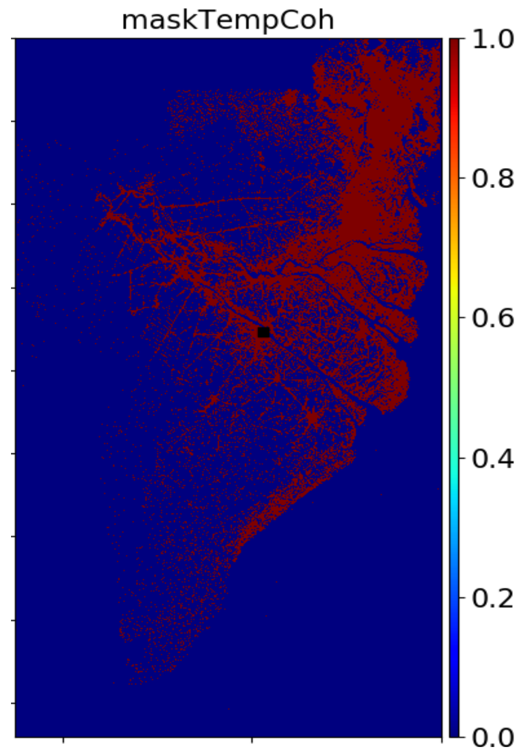
We multilook (i.e., 3x15) to reduce the data dimension.
We need three time memory to produce a simple network interferogram + one more time to store geometry information.

SBAS 4x 55x 17×10^8 /45 = 66 GB

We are able to do if RAM > 66 GB.



8412x4497 ~ 38×10^6



38×10^6

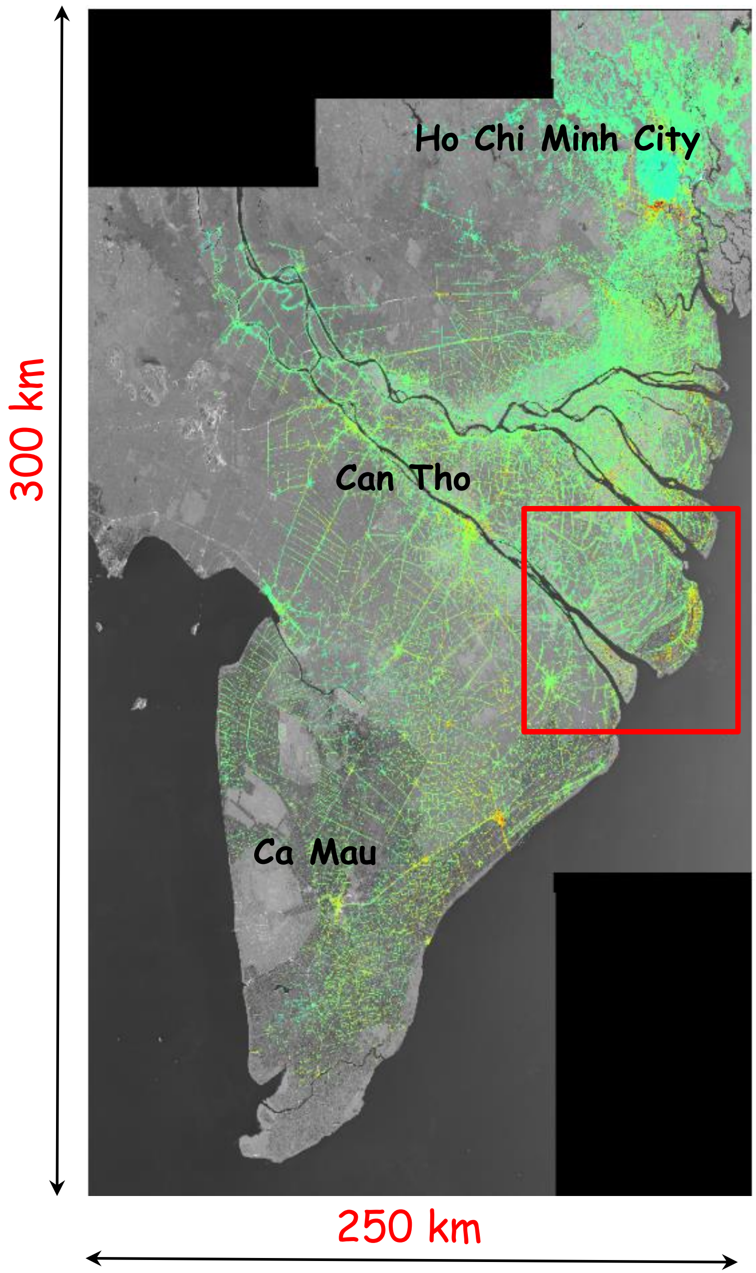
RAM consideration

3 swaths, 10 bursts each swath and 55 images: 55x25237x67469 ~ 55x 17×10^8

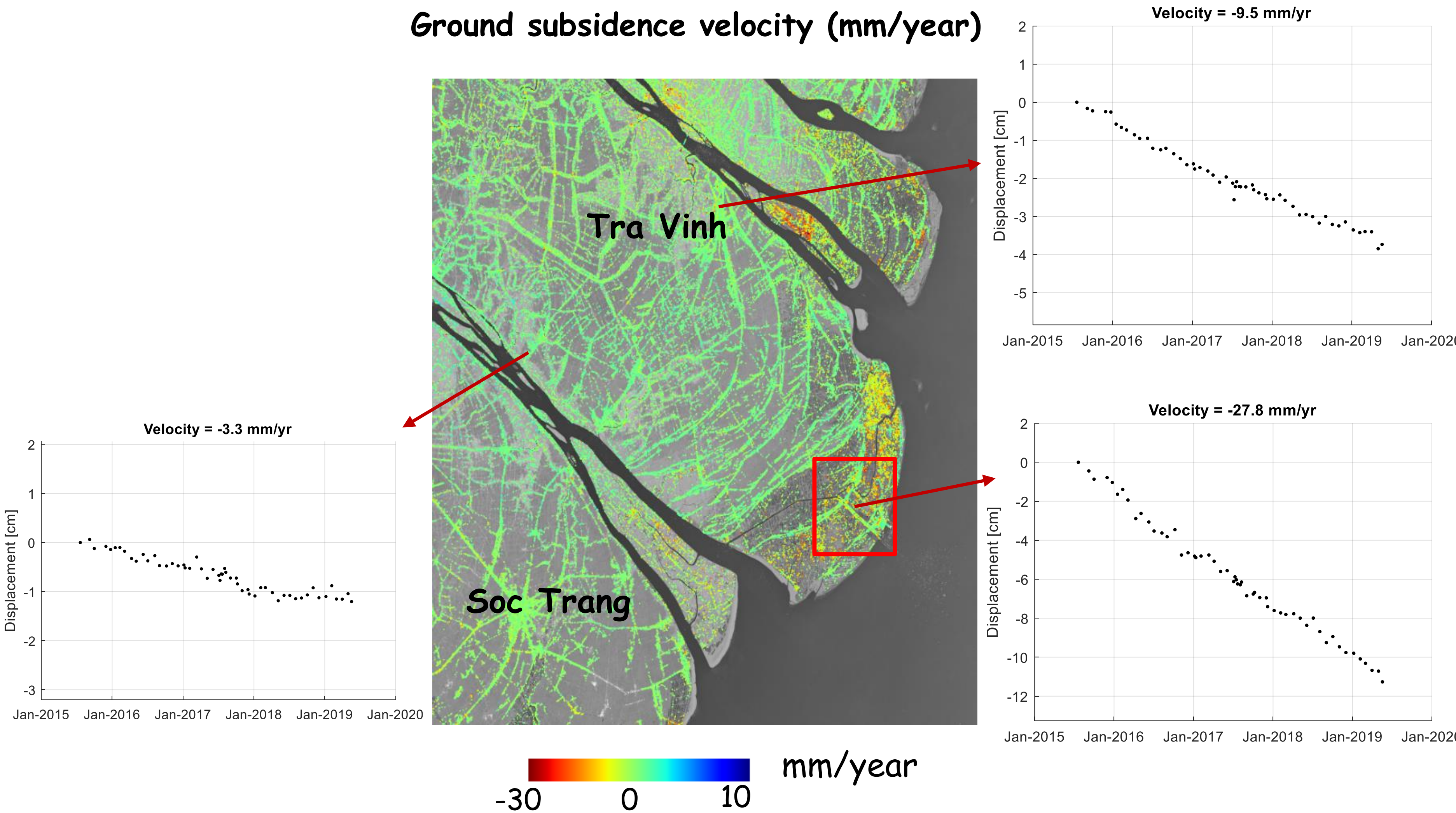
PSDS (i.e., TomoSAR) : Need 18 GB RAM (full resolution)

SBAS (i.e., MintPy) : Need 66 GB RAM (45 multilooks)

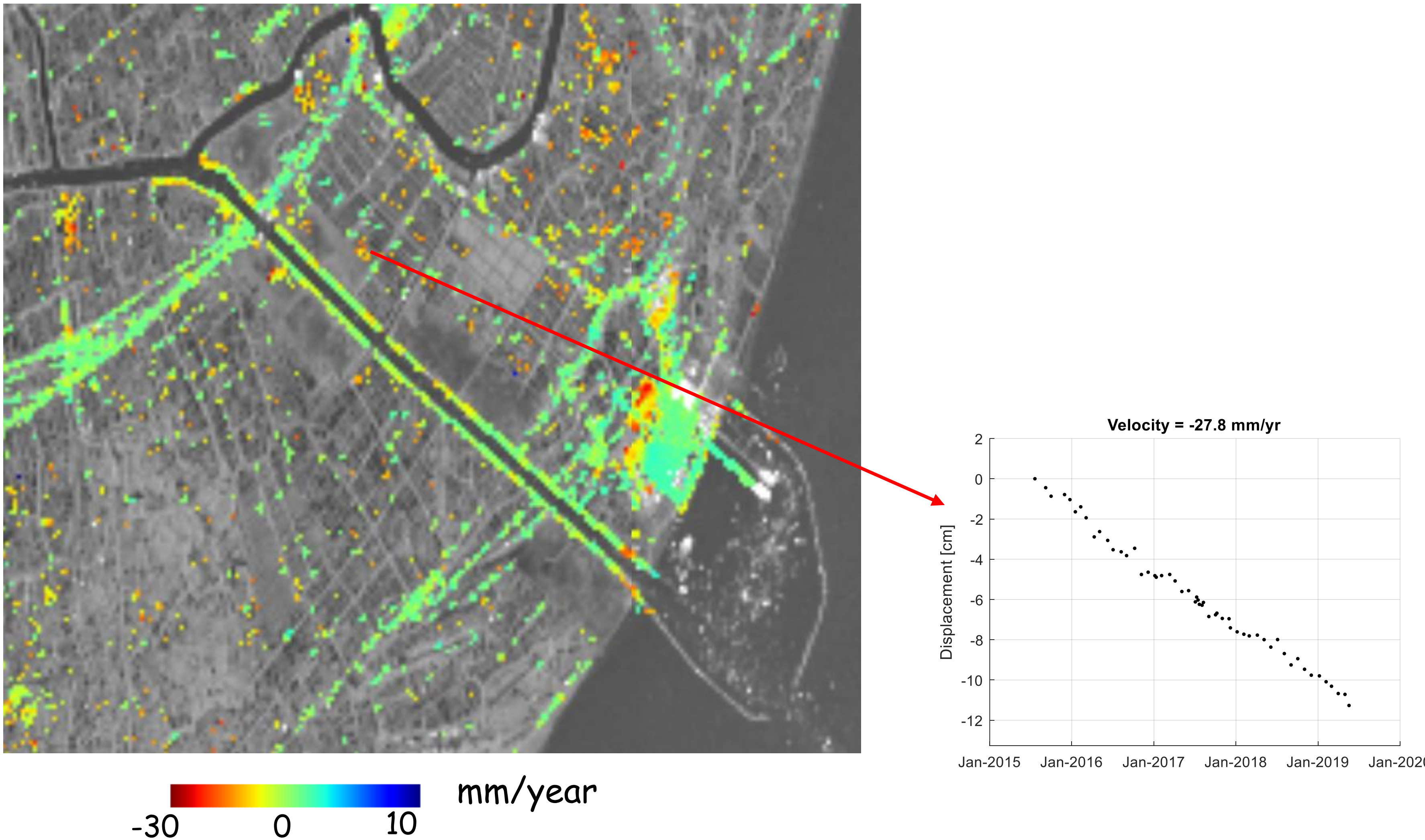
Delta-wide subsidence



Delta-wide subsidence



Delta-wide subsidence



So, with the capacity of RAM of 128/256 GB (in 2019), we can handle such 55 images Big Data.

- However, the problem is that we have more than 200 images at the moment (2014-2019) and much more in near future.

Perspective

- Is there a possibility to solve this problem ?

In the literature, there are many works relative to optimize for the pre-processing, **few publications** reports on adapted methods for the time series analysis.

1. With SBAS (i.e., **MintPy**), it always loads all the data and store at once. So, the best is select a subset to reduce the memory.
2. With PSDS (i.e., **TomoSAR**), it is possible to adapt the method to consider each layer (one image) only to process signal.

- How to ingest the new observations to the processed results ? Do we need to process again ?

- How fast is it ? Is is a couple of weeks or months ? Is this faster with cloud computing (i.e., HPC, AWS) ?

- Finally, all classical InSAR problem with Big Data: phase unwrapping, Deep Learning, phase calibration, ….

- **Look for future researches on methods and demonstrations.**

Look for paper research

remote sensing

an Open Access Journal by MDPI

IMPACT FACTOR 4.118

Synthetic Aperture Radar Interferometry in Big Data Era

Guest Editor:

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Deadline for manuscript submissions:
30 June 2020

Message from the Guest Editor

Dear Colleagues,

Synthetic Aperture Radar (SAR) Interferometry (InSAR) is a unique technology that widely used to measure ground subsidence and has already shown its ability to map such phenomena on a large spatial scale with millimetric accuracy from space. Sentinel-1 and the near future NISAR missions offer an unprecedented multi-temporal dataset of InSAR. Consequently, the processing of the Big Data is challenging for InSAR analysis techniques. This Special Issue is intended to present high-quality scientific review papers of existing achievements in the development and applications of InSAR techniques, or research papers that describe improved methods of InSAR in Big Data era; improved methods of interpretation of InSAR data; as well as demonstration InSAR Big Data applications. The recent Deep Learning technique for InSAR applications will also be included in this Special Issue.

https://www.mdpi.com/journal/remotesensing/special_issues/sar_big_data