FLATSIM Form@ter LArge-scale multi-Temporal Sentinel-1 Interferometry processing chain in MUSCATE

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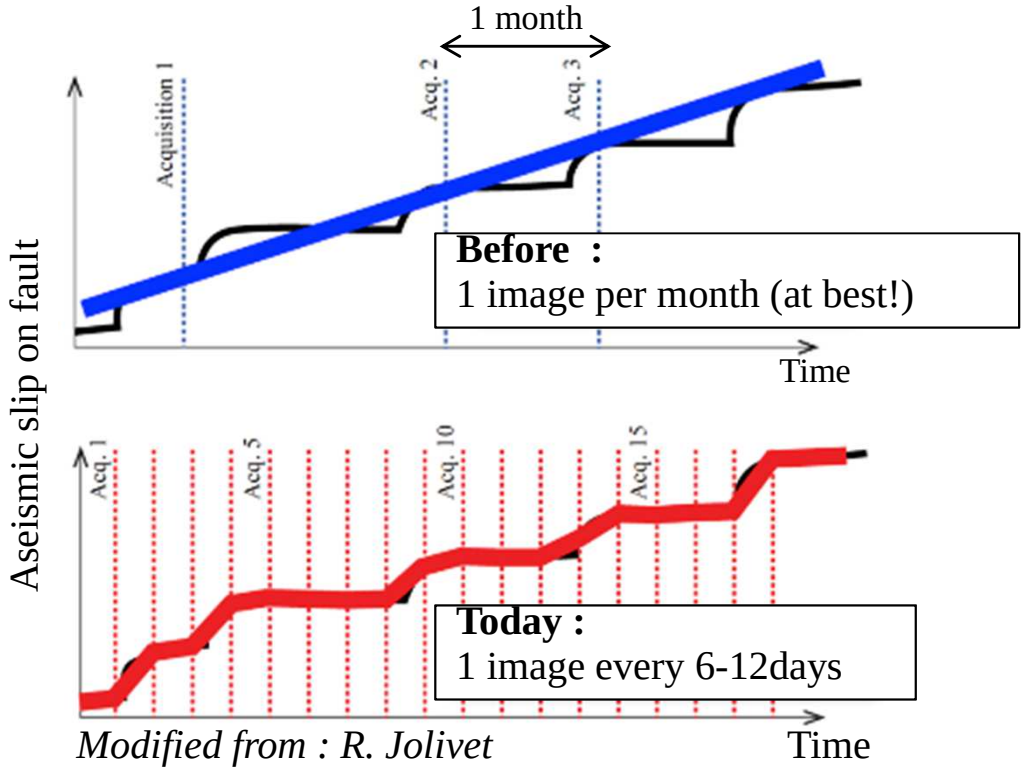
Marie-Pierre Doin, Erwan Pathier, Franck Thollard, Christophe Laurent (ISTERRE)

Sentinel 1 data : new opportunities and challenges for tectonic and natural hazards studies by InSAR



Modified from : R. Jolivet

High temporal resolution (6-12 days) **and** **Global coverage**

➟ **Towards studies of small transient deformation** ➟ **Towards studies of deformation at the continental scale**

FLATSIM will provide high temporal resolution time series **on large areas** prone to natural hazards

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OUTLINE

Based on Small Baseline processing chain (NSBAS, Doin et al., 2011, Grandin 2016)

FLATSIM : Form@ter **LA**rge-scale multi-**T**emporal **S**entinel-1 **I**nterferometry processing chain in **M**USCATE

Project Launch June 2016 with Form@ter scientific board

- **FLATSIM architecture at CNES**
- **NSBAS chain and outputs**
- **First preliminary results**
- **Data policy and perspectives**

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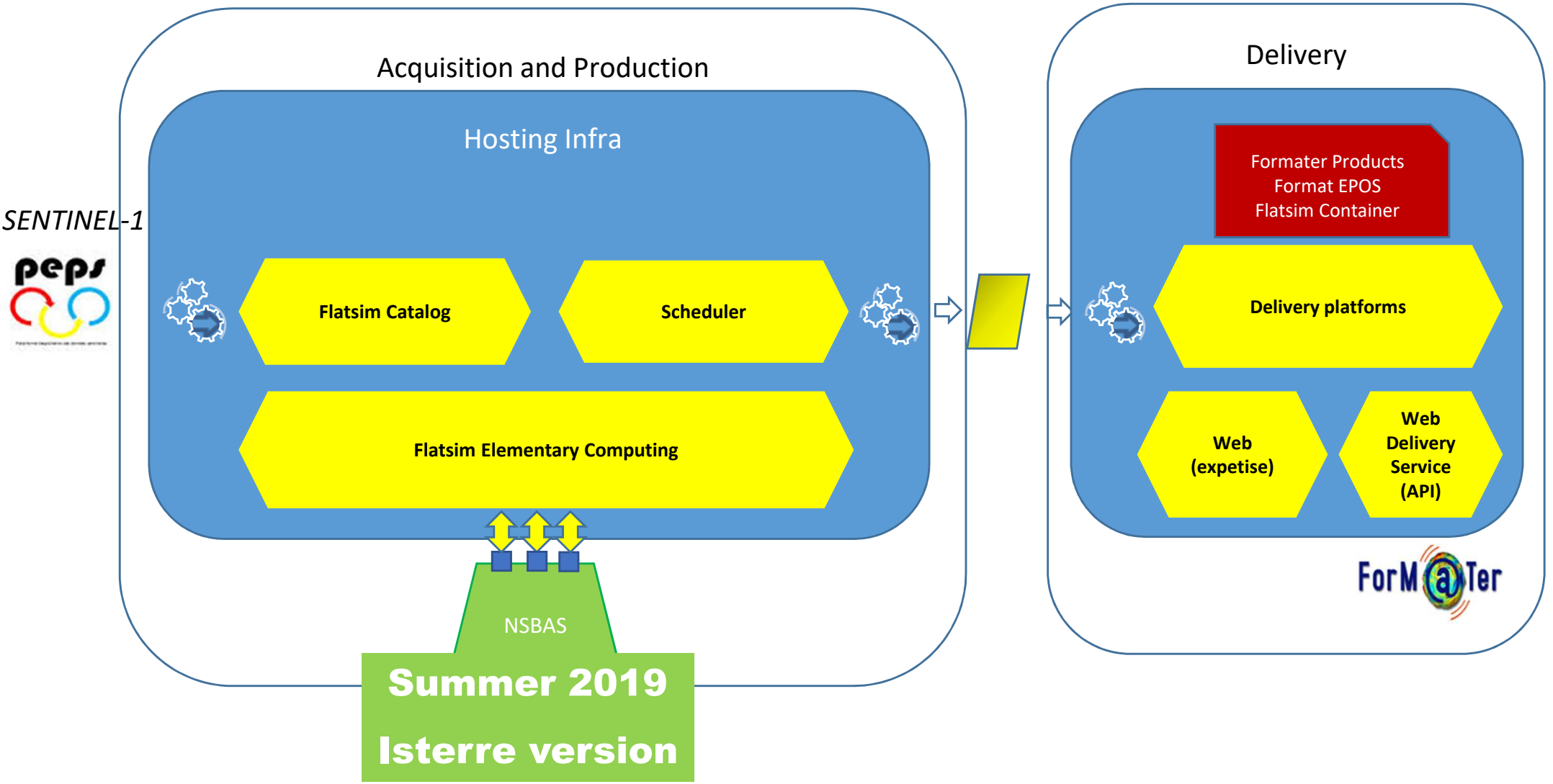
FLATSIM architecture at CNES



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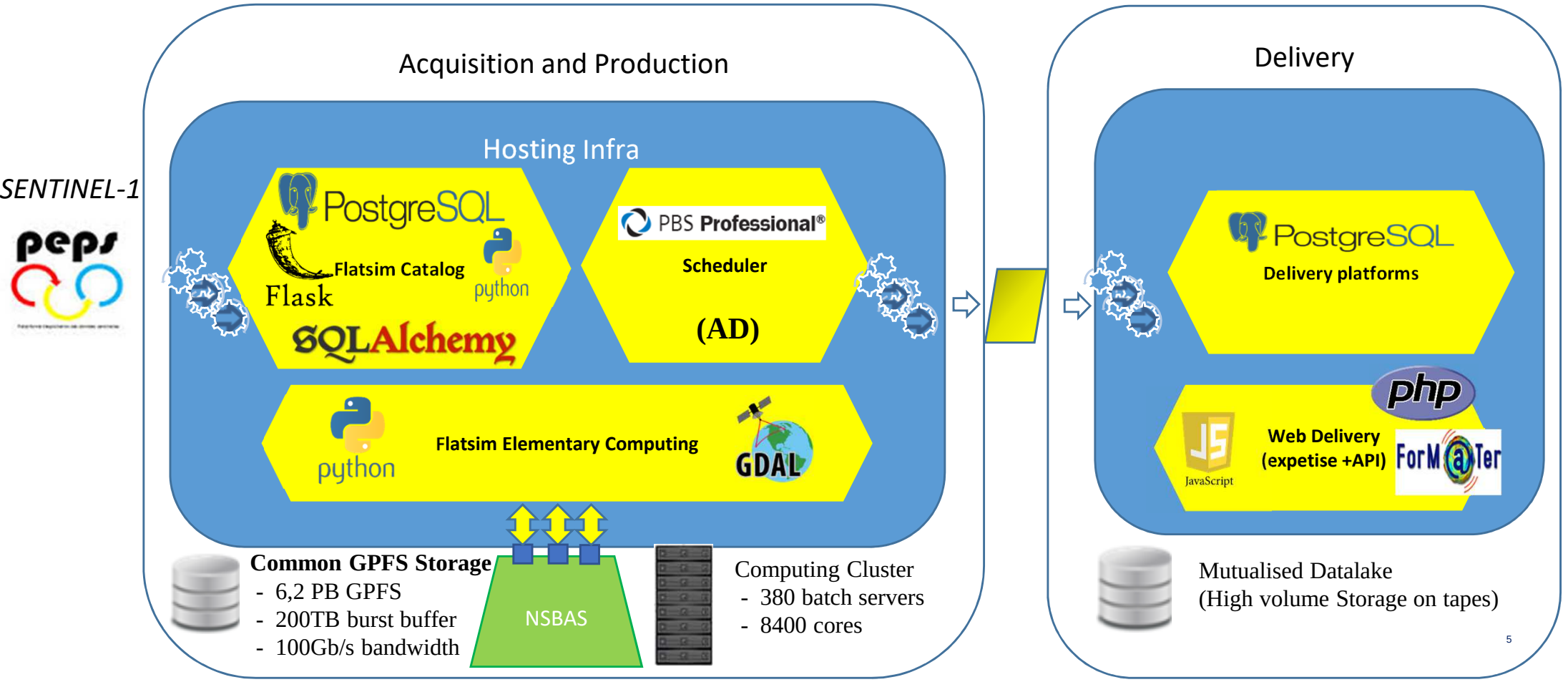
FLATSIM architecture at CNES

SOFT and HARD ware



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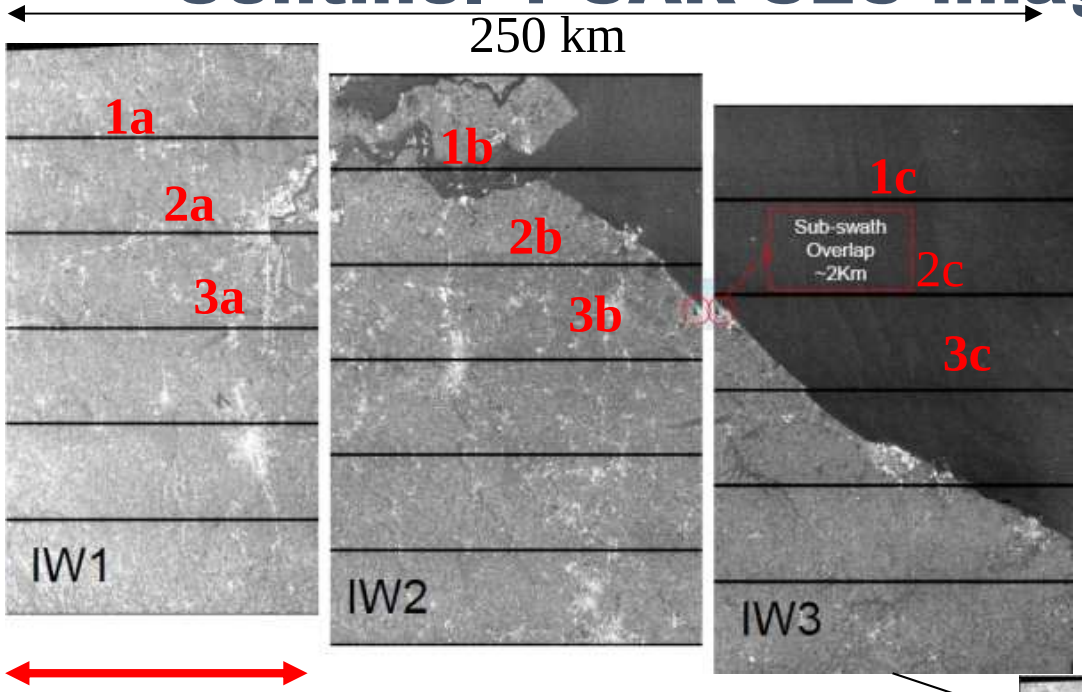
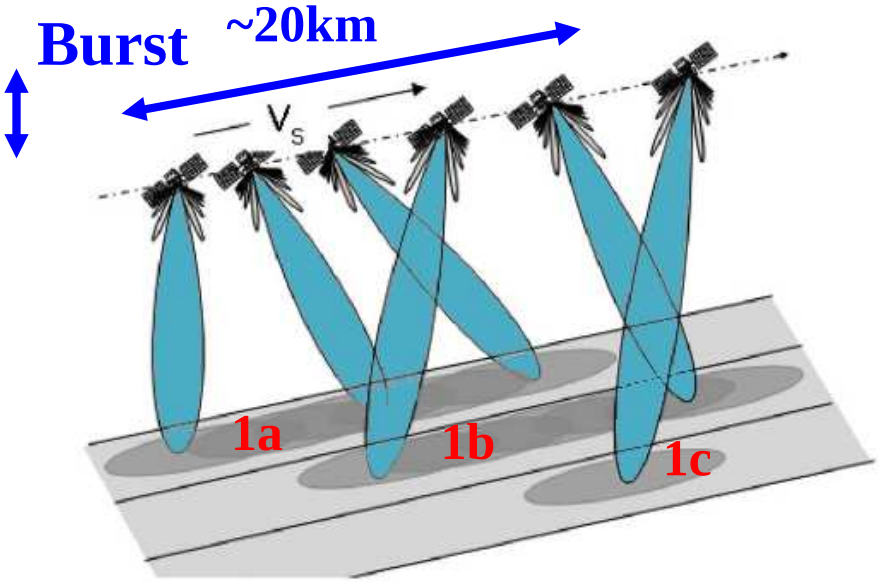
NSBAS chain and outputs

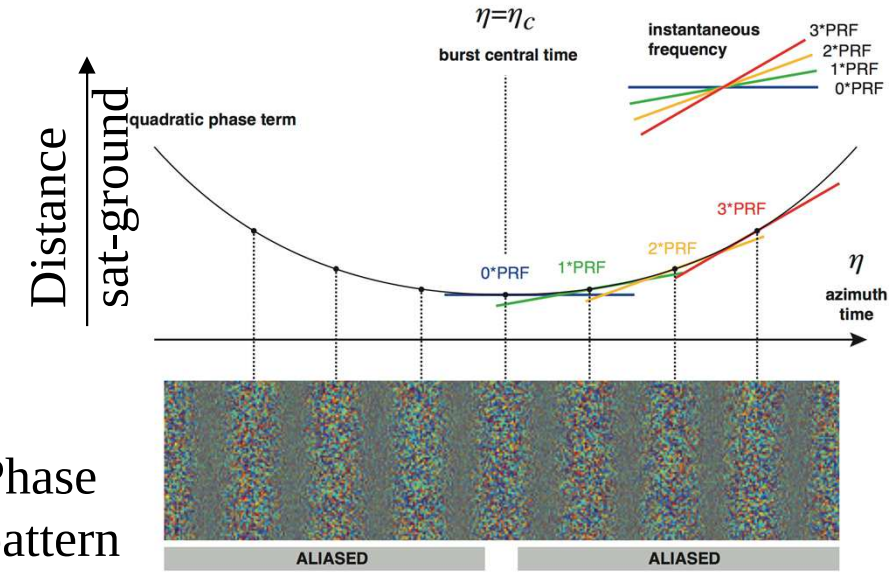
Sentinel-1 SAR SLC image



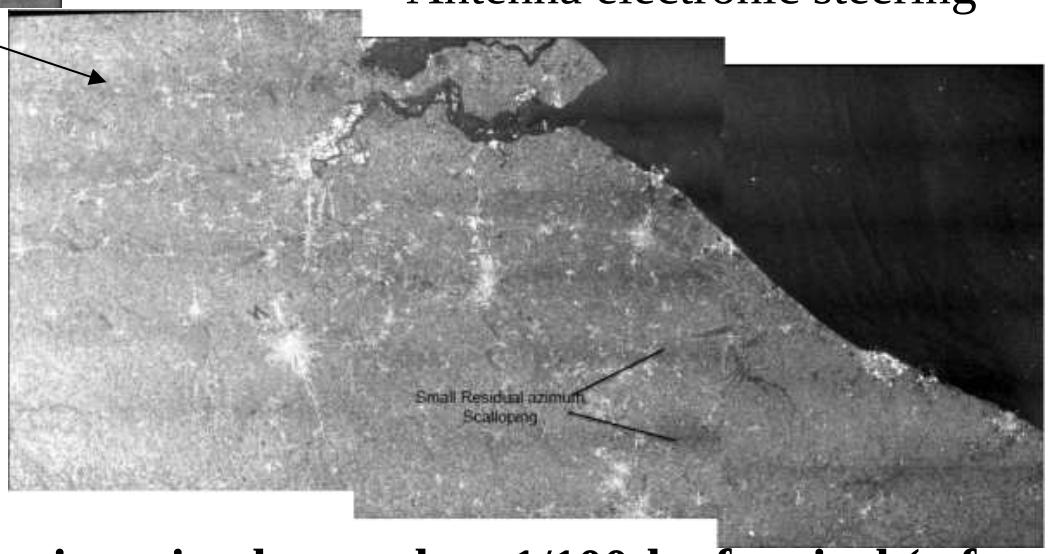
Subswath



Antenna electronic steering



Phase pattern



Coregistration better than 1/100th of a pixel (a few cm)

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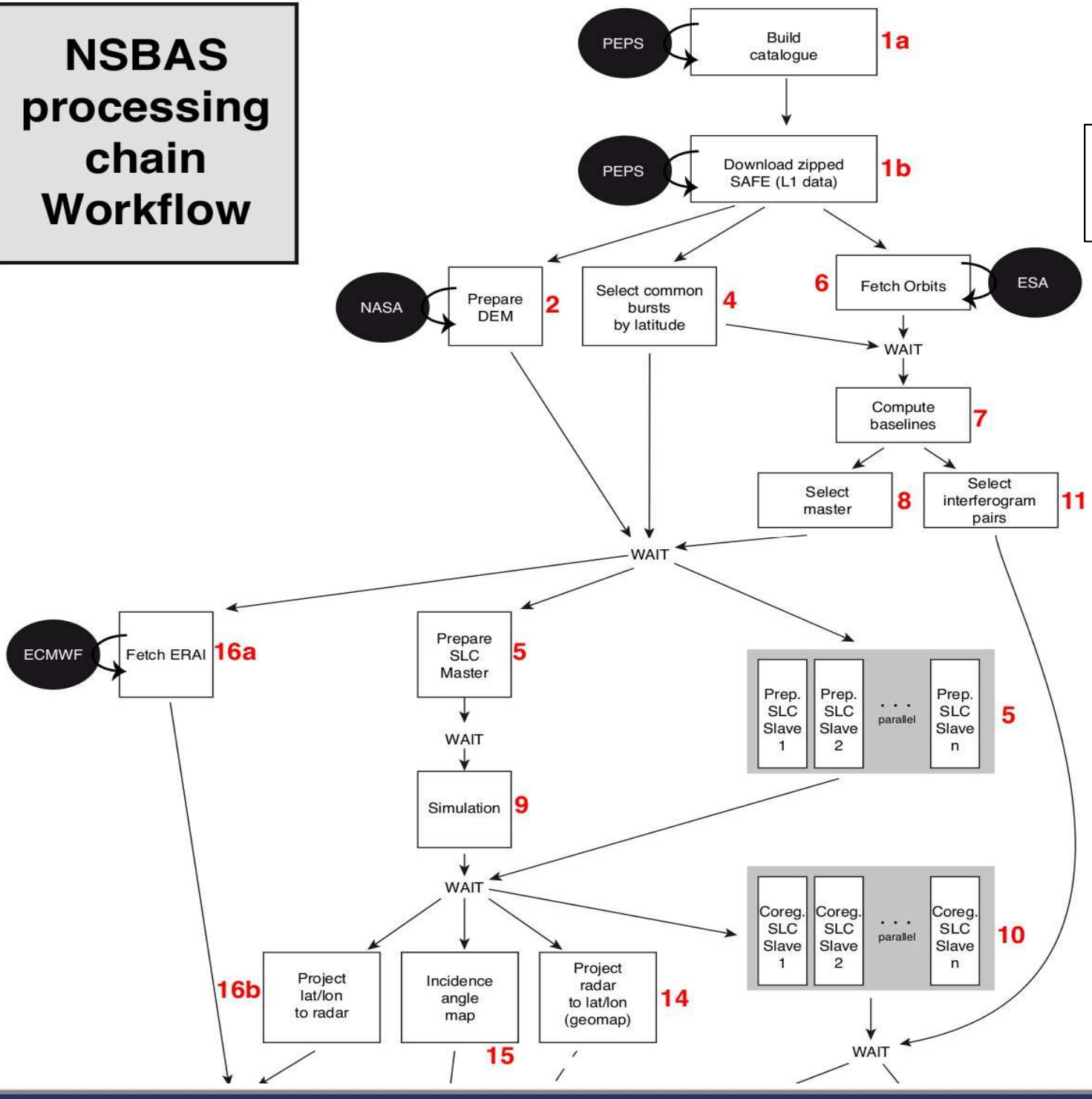
NSBAS processing chain Workflow



Data Catalog : from CNES
SLC data : from CNES

Bursts selection

SRTM DEM from USGS
Precise orbits from ESA
Atmospheric model :
ERA 5 from ECMWF

Simulation of the radar image geometry
Coregister all images on a master image

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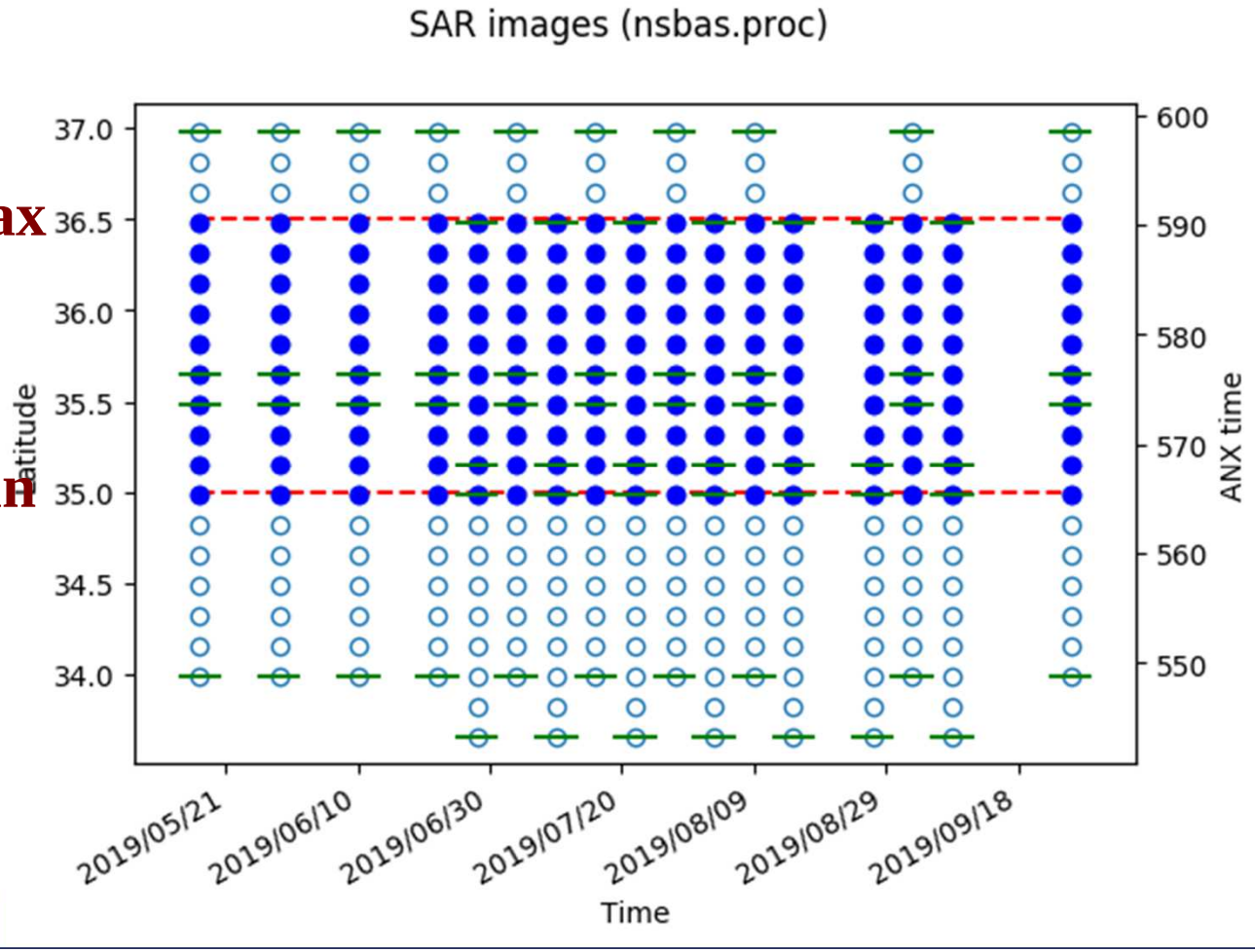
NSBAS chain and outputs

burst selection per subswath based on latitudes min and max entered in ROI
Dates not complete between selected latitudes for all subswaths are rejected

Concatenated SAFE (up to 4 successfully tested on Tibet)

Lat Max

Lat Min



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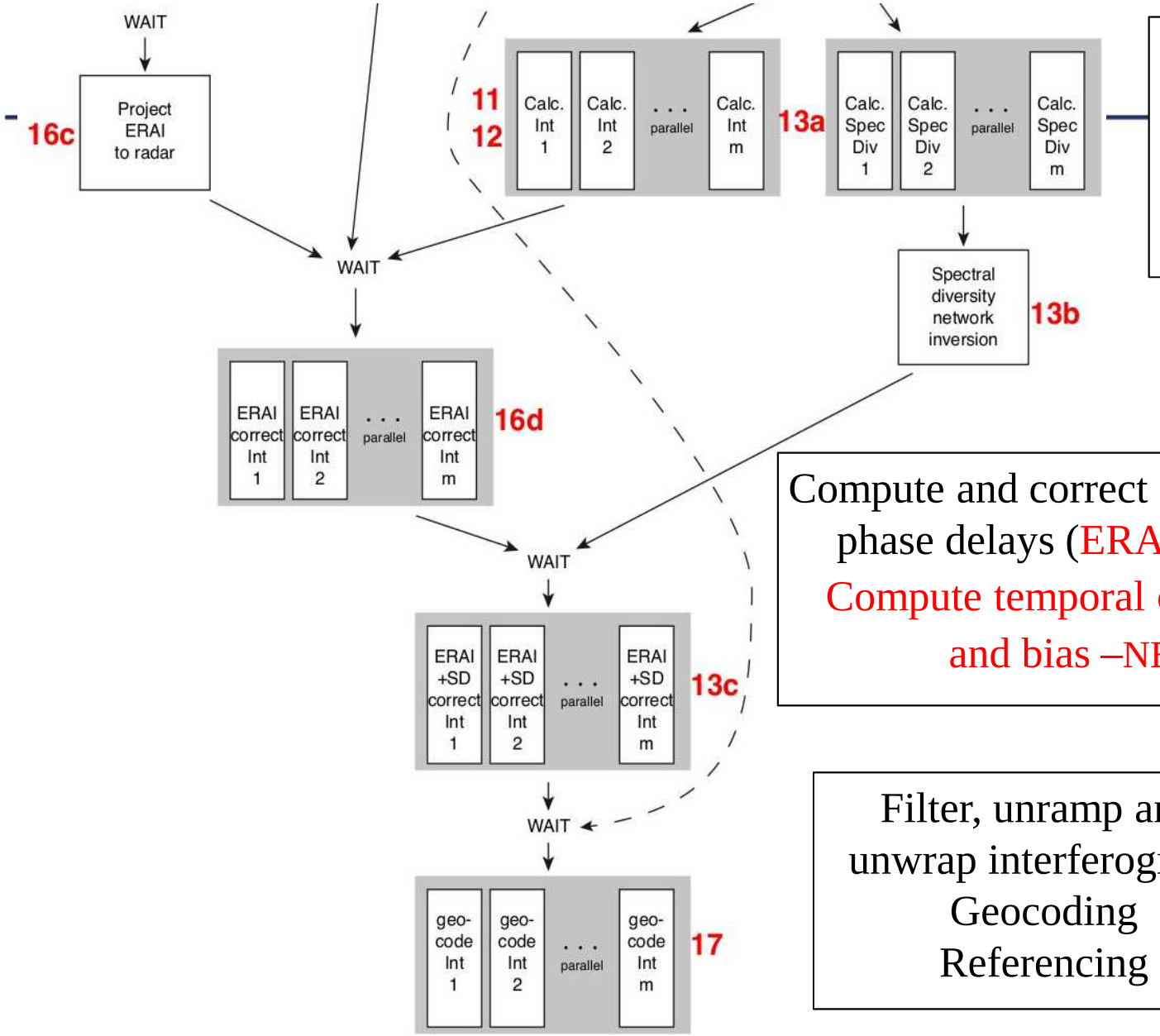

Generate interferograms
Measure and substract the effect of antenna steering
Merge sub-swaths - NEW

Compute and correct atmospheric phase delays (ERA5 – NEW)
Compute temporal coherence and bias –NEW

See MP. Doin's talk on Wednesday pm

Filter, unramp and unwrap interferograms
Geocoding
Referencing

Inversion of the network : Unwrapping error correction - NEW
Error estimate
Time series

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NSBAS chain and outputs

FLATSIM distributed products

Code Flatsim	Description	Acronym	Content Summary
INTERFEROGRAM	Wrapped Differential Interferograms	InW	b1: wrapped phase, b2: master image's amplitude
INTERFEROGRAM	Wrapped Differential Interferograms (Higher Resolution)	InW	As above, HR
INTERFEROGRAM	Spatial coherence	Coh	b1: spatial coherence, b2: average amplitude
INTERFEROGRAM	Unwrapped Differential Interferogram	InU	b1: unwrapped phase, b2: master image's amplitude
INTERFEROGRAM	Interferogram Atmospheric Phase Screen from Global Atmospheric Model	APS	b1: APS, b2: simulated amplitude
AUXILIARYDATA	Map of LOS vector (NEU coefficient)	CosNEU	b1: E, b2: N, b3: U components of LOS vector
AUXILIARYDATA	DEM in radar geometry	DEM	b1: elevation, b2: simulated amplitude
AUXILIARYDATA	Lookup tables to pass from radar to ground geometry and vice versa	LuT	b1: azimuth, b2: range for each DEM pixel
AUXILIARYDATA	Lookup tables to pass from radar to ground geometry and vice versa (Higher resolu	LuT	As above, HR
TIMESERIES	TIMESERIES	DTS-LOS	Cube with inverted phase at each time step
TIMESERIES	Temporal Coherence (Quality of measure) (Higher resolution)	Tcoh	b1: temporal coherence proxy (HR), b2: bias,
			b3: SLC amplitudes' stack, b4: dispersion of SLC amplitudes
TIMESERIES	Network misclosure (Quality of times series inversion)	Net	b1: misclosure map,b2:number of inverted ifgs per pixel,
			b3: number of inverted images per pixel, b4: temporal coherence proxy, b5: bias
TIMESERIES	Mean LOS velocity	MV-LOS	b1: mean velocity, b2: simulated amplitude
TIMESERIES	Stack of coregistered Interferograms	Stk-In	Text file with names of coregistered ifgs used in stack

Metadata

Geotiff with png

Tiff in SAR geom with png

+ Auxiliary Files with key Parameters

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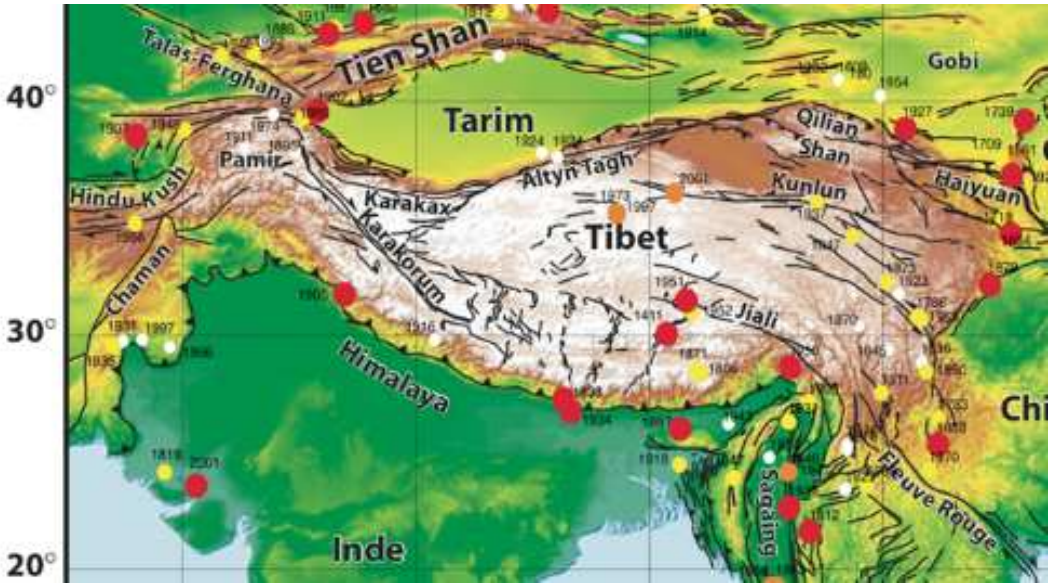
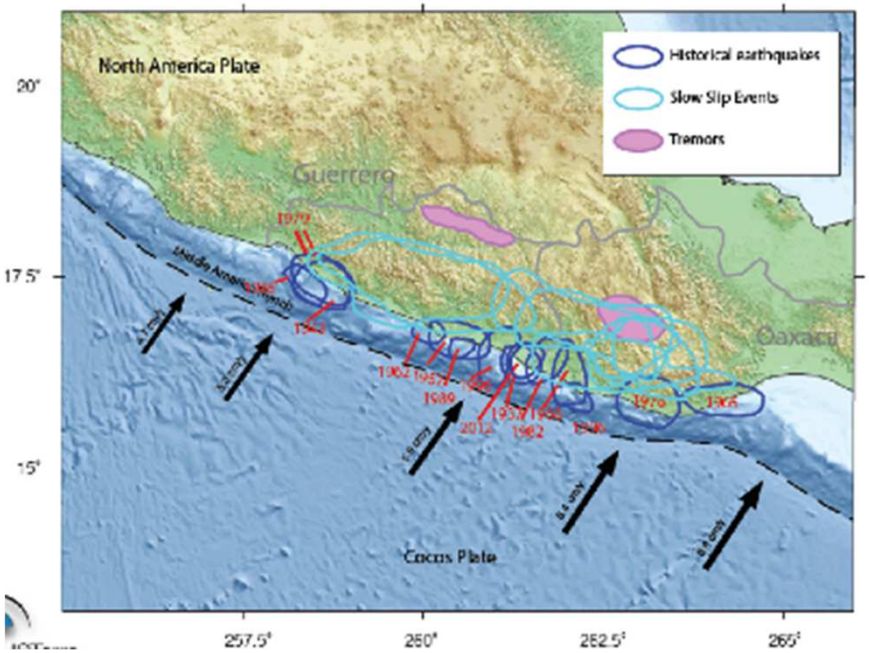
First preliminary results

2 sites involving two PhD students co-funded by CNES (L. Lemrabet and L. Maubant)

Tibet



Mexico



Among the main scientific questions :

- Spatio-temporal behavior of seismic and aseismic slip on faults ?
- Partitioning of deformation at different scales ?
- On- and off-fault deformation ?

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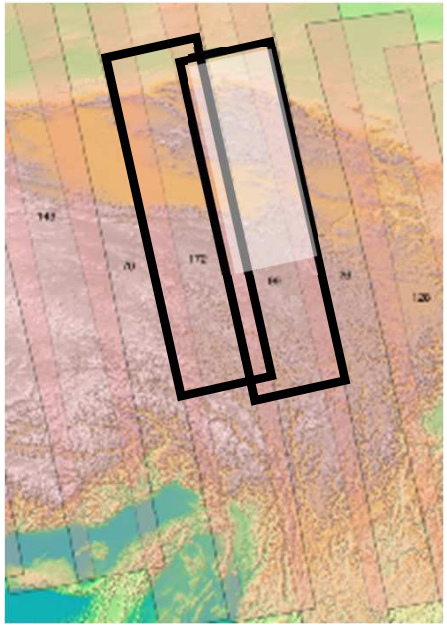
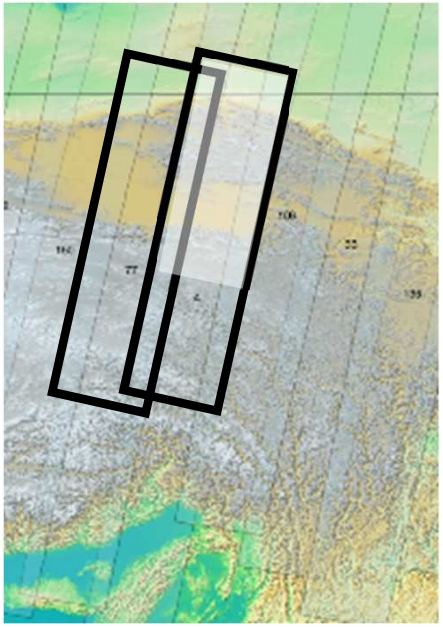
First preliminary results

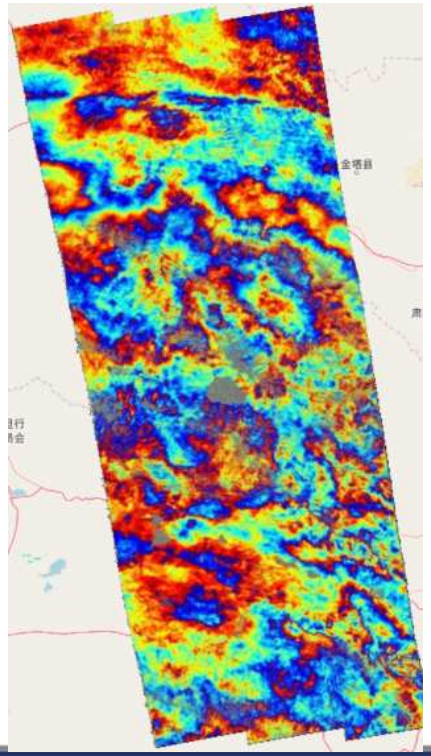
Tibetan plateau

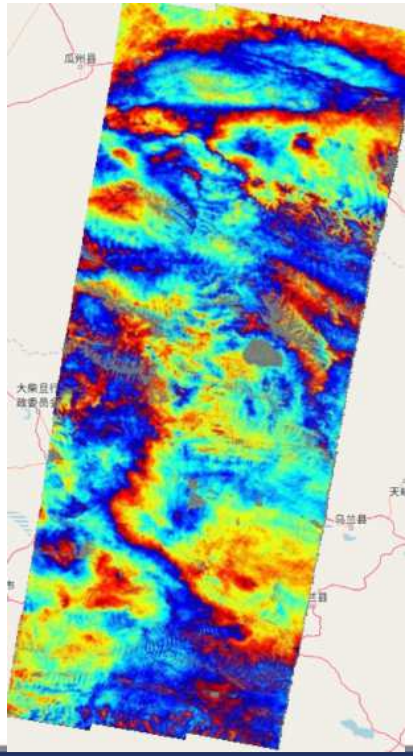


Ex. of 6 days interferograms



1 color cycle = 2.8 cm





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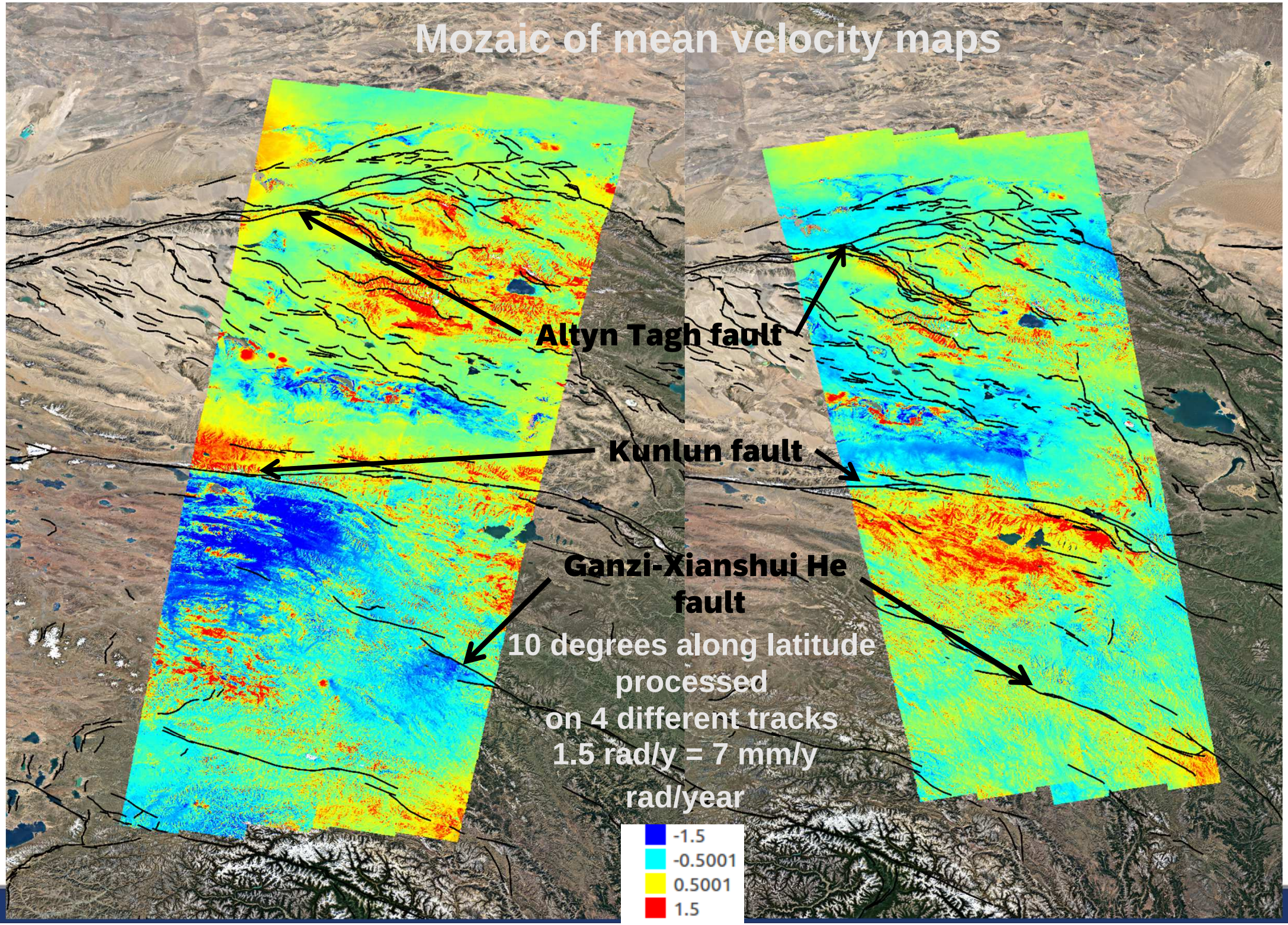
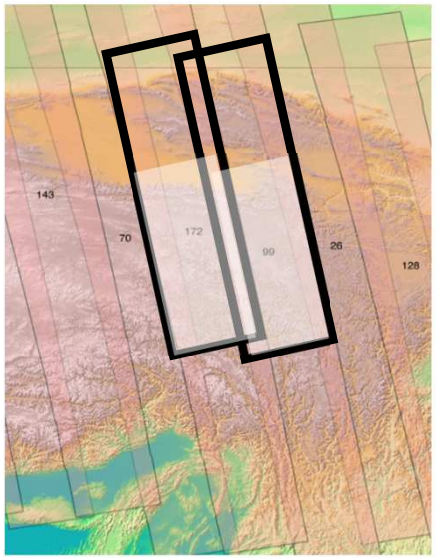
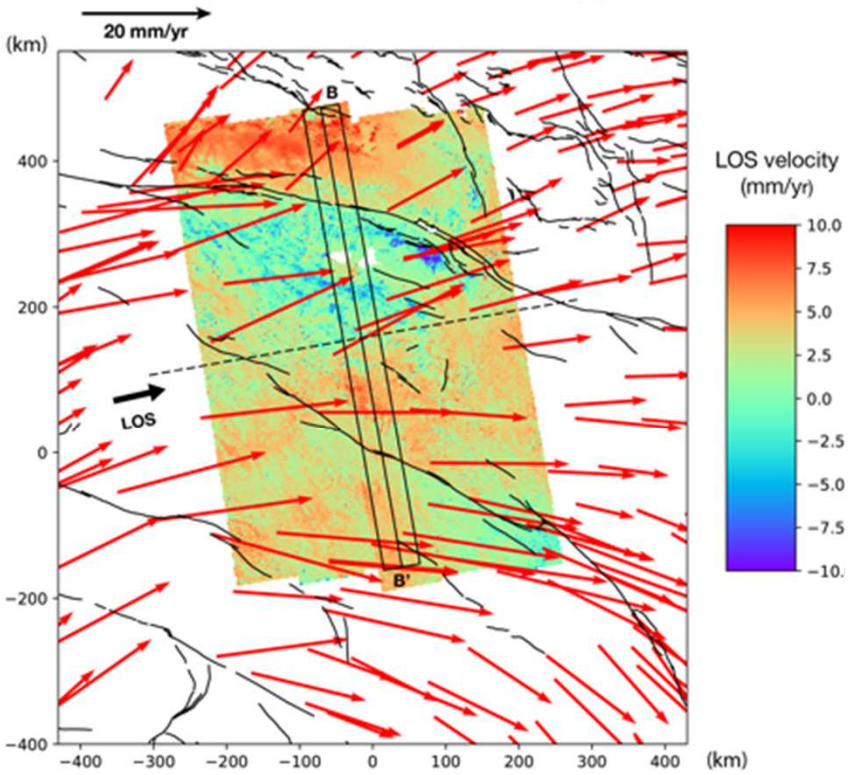
Mozaic of mean velocity maps

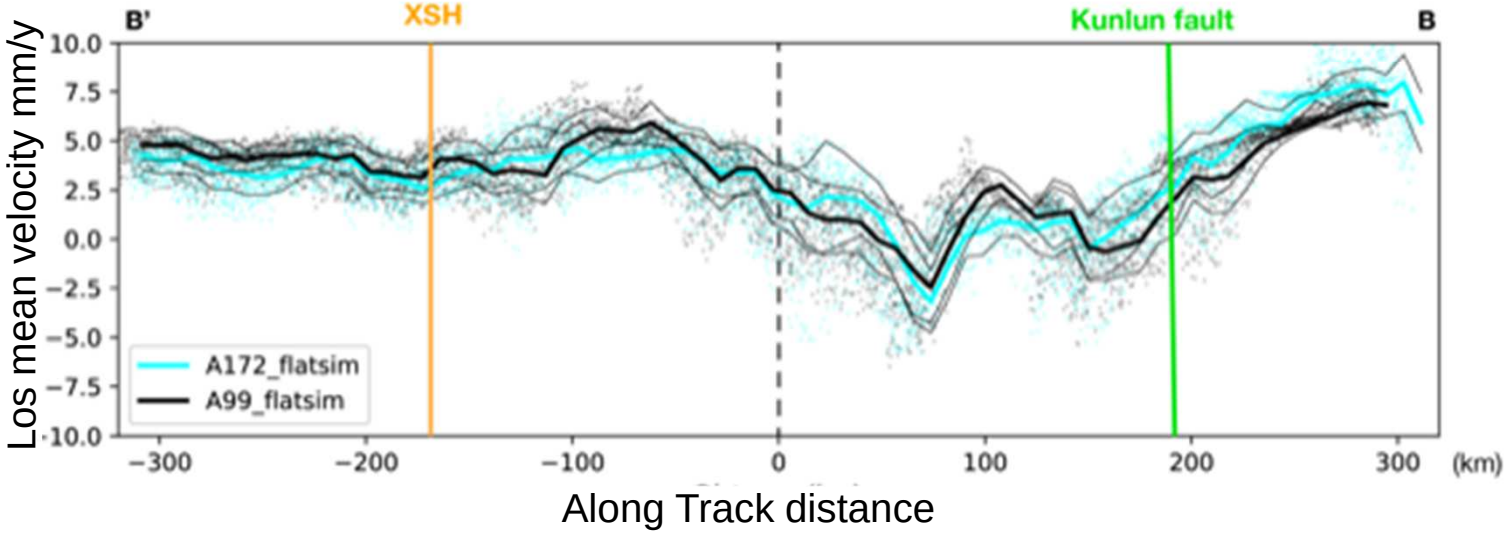


First preliminary results

Comparison of mean velocity maps in overlapping areas







Along Track distance

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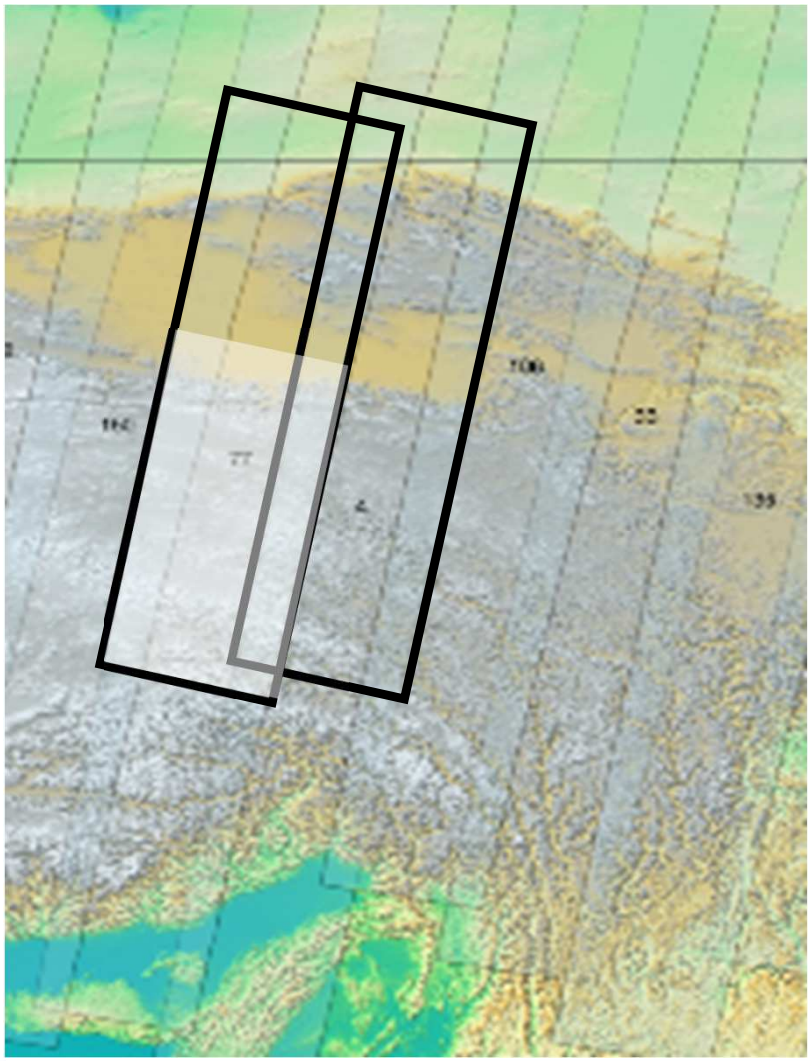
First preliminary results

Example of time series :

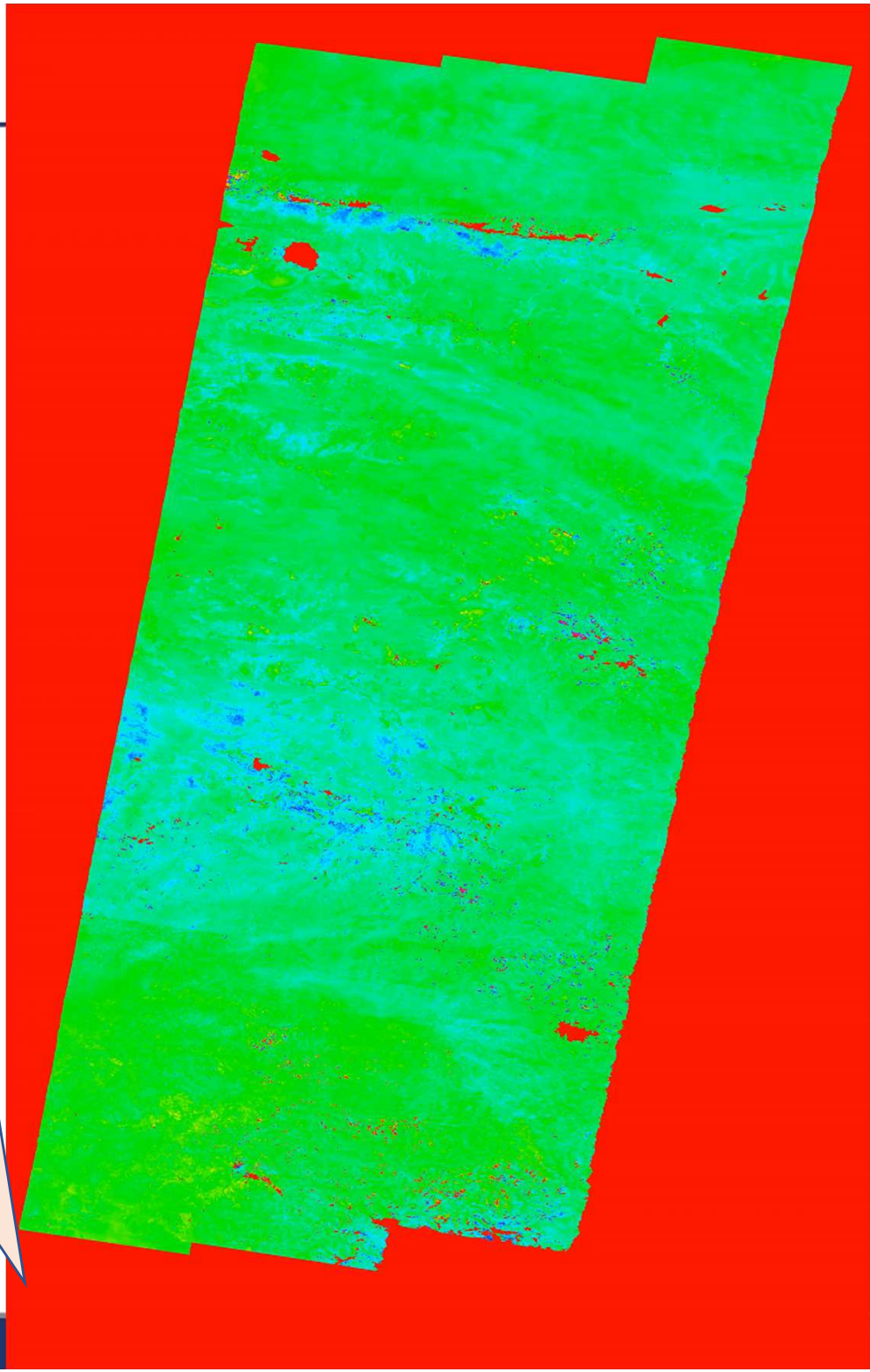
Southern part of the West track



MASK in RED

Video visualizing the **cumulated distance** over a 4.5 years period

-10 rad +5



First preliminary results : computing figures

4 orbit tracks (2 asc 2 desc)
split in 2 sub-zones
8 areas composed of 32 S1 SAFE
1 200 000 km² of data with overlaps
5 interferograms/date : n+1,n+2,n+3,n+3m,n+1y

Sites	Nb of Dates	Nb of interferograms
TIBETA099NORD	98	430
TIBETA099SUD	97	429
TIBETA172NORD	99	429
TIBETA172SUD	99	418
TIBETD004NORD	81	347
TIBETD004SUD	79	337
TIBETD077NORD	88	384
TIBETD077SUD	91	393

- Storage used on Catalog **160 To in total**

4.2 To of auxiliairy data, and 155.6 To for **52 602 products**

- 11To 3045 SLC S1 SAFE products with VV polarisation only (2 956 S1A et 89 S1B)
- 27To of co registered SLC (2210 products)
- 18To of raw interferograms (9582 products)
- 29To of interferograms corrected with spectral diversity (9582 products)
- 15To of **interferograms with full IW swath** (**3194 products**)
- 49To of interferograms after filtering, atmospheric correction, unwrapping, geocoding (3 179 products)
- 6.2To of interferograms shaped for delivery (3167 products)
- 310Go of multi temporel series (8 products)
- 64Go of multi temporel series for delivery (8 produits)
- 22Go auxiliairy data for delivery (8 produits)

- Storage used on expert website :
  - 6.2 To of web data (zip archive)
  - 34 Go of web previews (wms, quicklooks, thumbnails, legends)

- processing :
  - 45 705 Jobs sur le cluster (41631 OK / 4074 KO)
  - **76 410 Cpu hours**
  - 8.3 Go of log files
  - 50To space reserved for processing

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Perspectives

We are proud of these preliminary results that follows CNES and Form@ter commitment in MDIS-2017 : this project give the opportunity for laboratories to process large areas, impossible for them to produce, due to the data volume

The project is still in a validation phase

- Consolidation phase on the 2 first sites

- Cross validation (with GPS, PS, in situ data) on well instrumented areas maybe on a new site to be defined (France, California, active seismic areas, volcanic provinces, etc)

- New test sites to be decided within the Form@ter community or steering committee on expressed needs. Need for a scientific call ?

CNES has committed to process a surface about 7 times France (4 million of km2) at a time as a first step and evaluate what will be possible for the cluster

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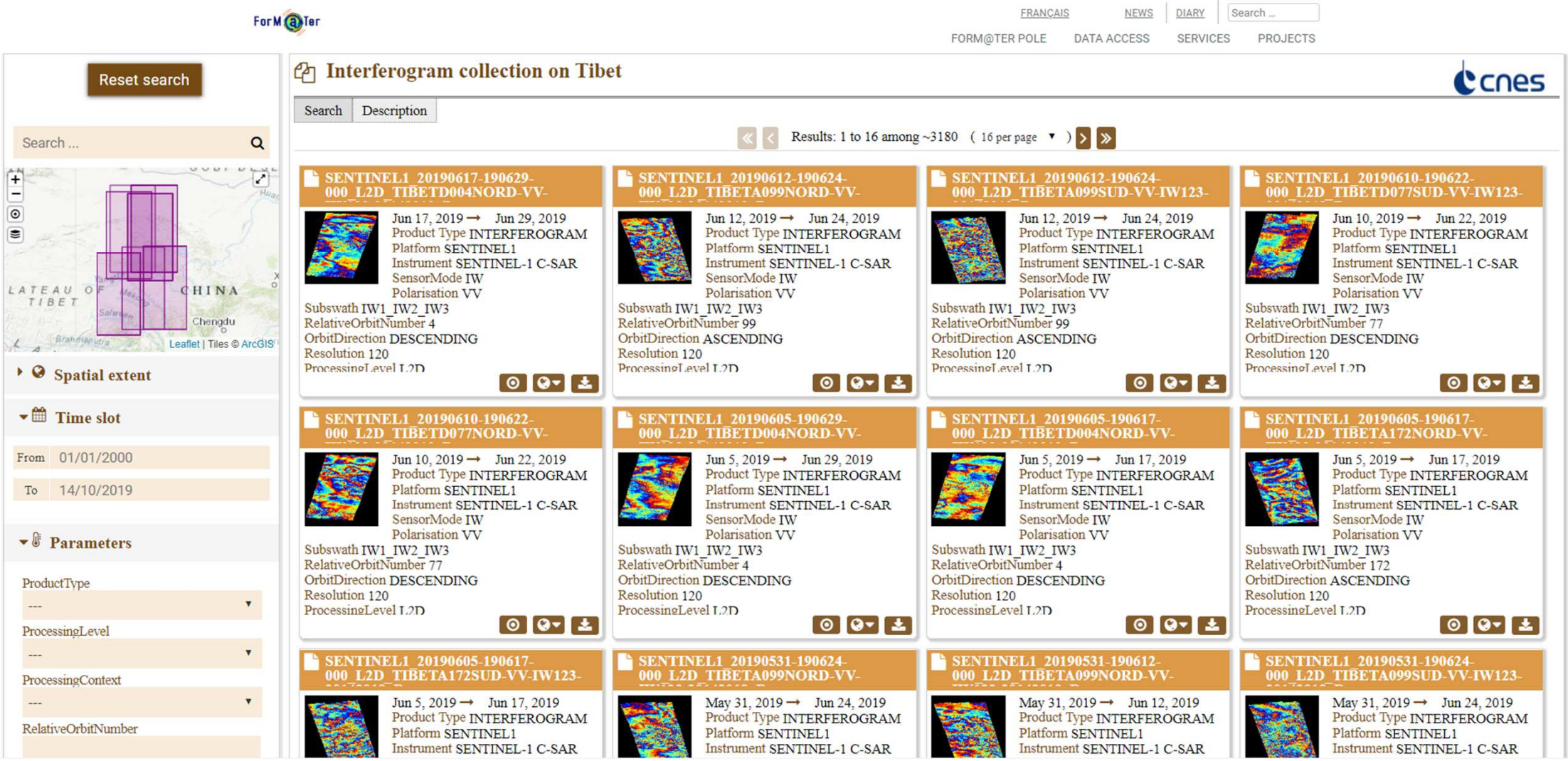
Data policy

Access to products when validated from the ForM@Ter website

See also Emilie Ostenciaux presentation in next session

We will define data access policy and data availability to the community



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Thank you