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ESA–MOST Dragon Cooperation
中国科技部-欧洲空间局“龙计划”合作
2017 DRAGON 4 SYMPOSIUM
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26–30 June 2017 | Copenhagen, Denmark
2017年6月26-30日，丹麦 哥本哈根

InSAR monitoring of ground motion in response to climatic or tectonic forcing : from the exploitation of the Envisat archive to the processing of the Sentinel-1 database over the Tibetan plateau

Team and co-authors

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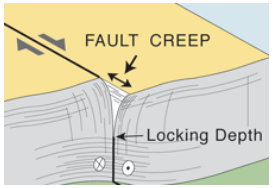
- IPG, Paris : **R. Grandin, L. Barrier, A. Dransart-Laborde**
- LGLTPE, Lyon : **H.-P. Leloup**
- Institute of Geology, CEA, Beijing : **Sun Jianbao**
- Institute of Geology, CAGS, Beijing : **M.-L. Chevalier, Li Haibing**
- Peking University, Beijing : **Shen Zheng-Kang**
- University of California, Los Angeles : **G. Peltzer**

YOUNG SCIENTISTS :

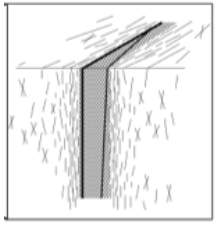
S. Daout (ex-PhD, ISTerre), L. Lemrabet (MSc, ISTerre)

Overall project objectives

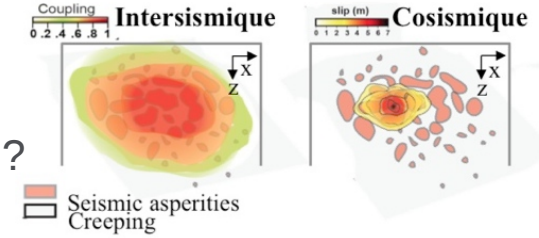
How to improve our vision of fault interseismic coupling ?



Which fault properties and physical processes control seismic versus aseismic slip ?

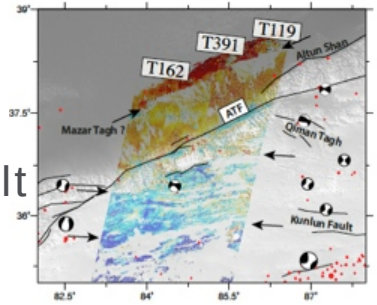


Which link between interseismic and coseismic behavior ?



How does slip partition between faults ?

How important is off-fault deformation ?



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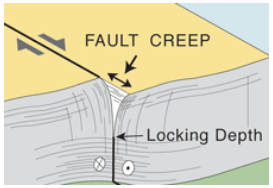

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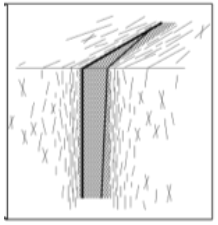

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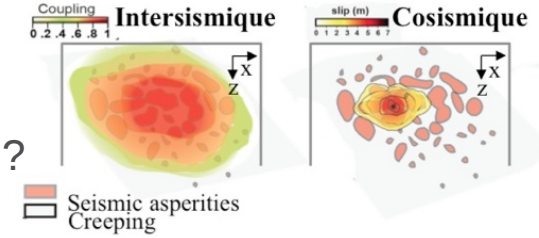

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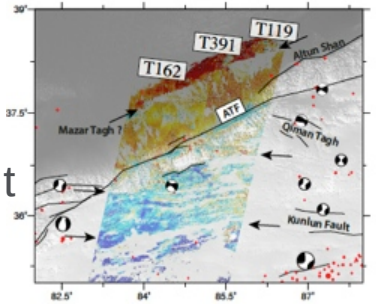


- **Toward high temporal resolution InSAR time series and large scale InSAR studies of continental deformation**

Challenges : Big Data ; Noise/Signal decorrelation ; GPS/InSAR joint inversion

Outline of the talk

1 - Exploiting the complete Envisat archive :

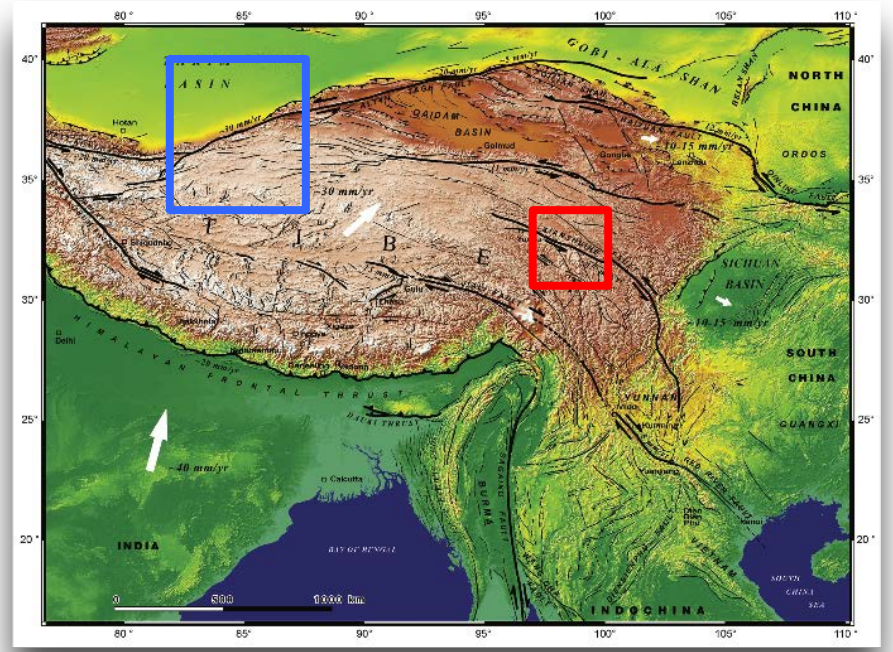
Slip partitioning in the northwestern part of the Tibetan plateau

(Daout et al., to be submitted, 2017)

2 - Exploiting the new Sentinel-1 database :

Present-day strain accumulation across the Ganzi fault (SE China)

(L. Lemrabet, MSc work, see also poster #32)



(Tapponnier et al., 2001)

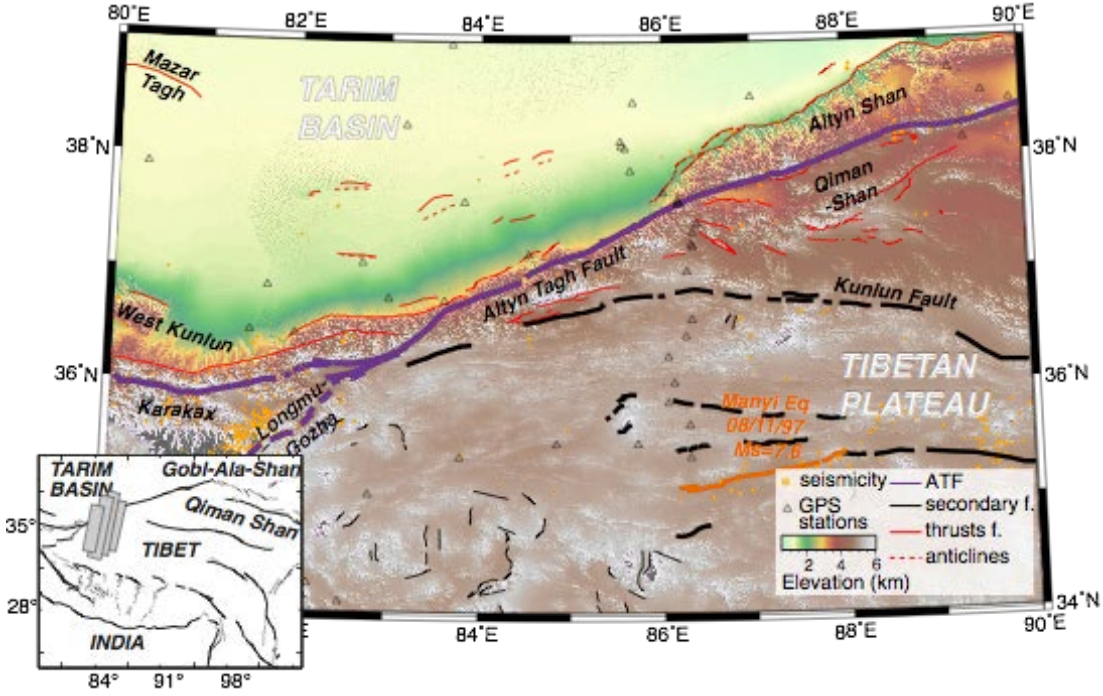
1 – Slip partitioning in NW China, from Envisat InSAR time series

- TECTONIC SETTING :

Left-lateral Altyn Tagh, Kunlun, Manyi faults

Thrusts in Western Kunlun Shan (2016 Pishan EQ), Altyn Shan and Qiman Shan

Extension (2014 Yutian EQ)



1 – Slip partitioning in NW China, from Envisat InSAR time series

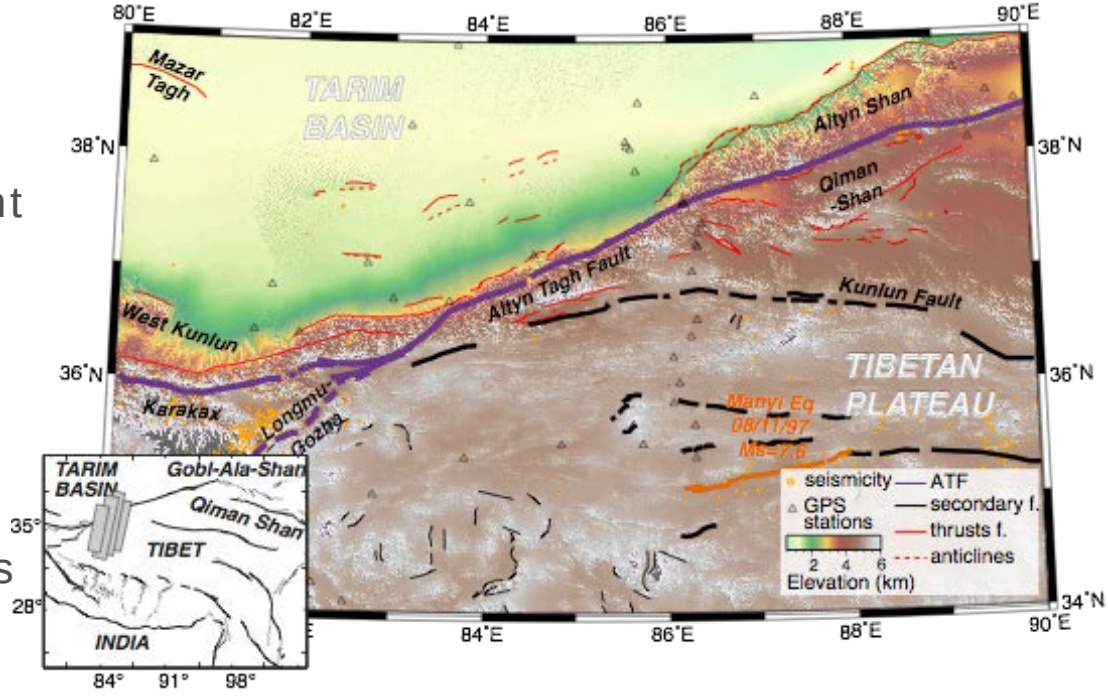
- MAIN QUESTION :

How is the deformation currently partitioned in between these different fault systems ?

- APPROACH :

No seismicity, no GPS

=> large-scale InSAR measurements

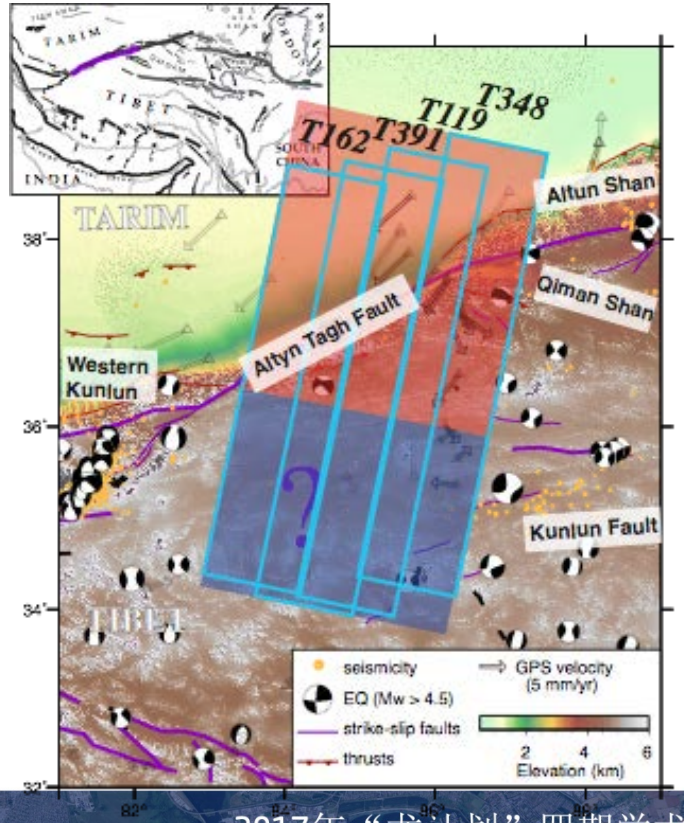


1 – Slip partitioning in NW China, from Envisat InSAR time series

- InSAR data set :

Envisat 2003-2011

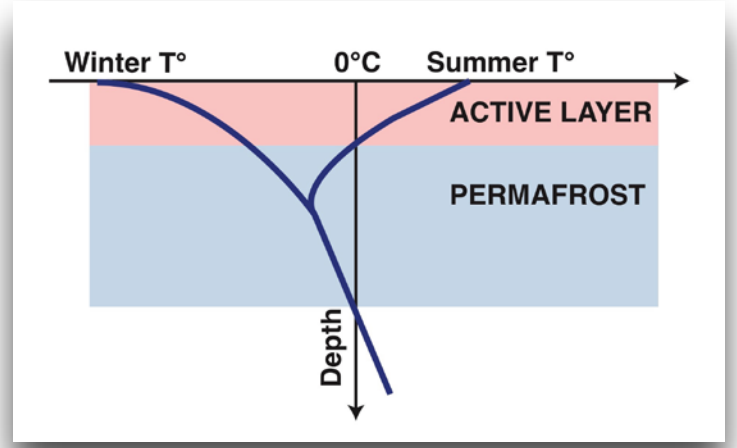
4 tracks, 600 km-long, from the Tarim basin to the central tibetan plateau

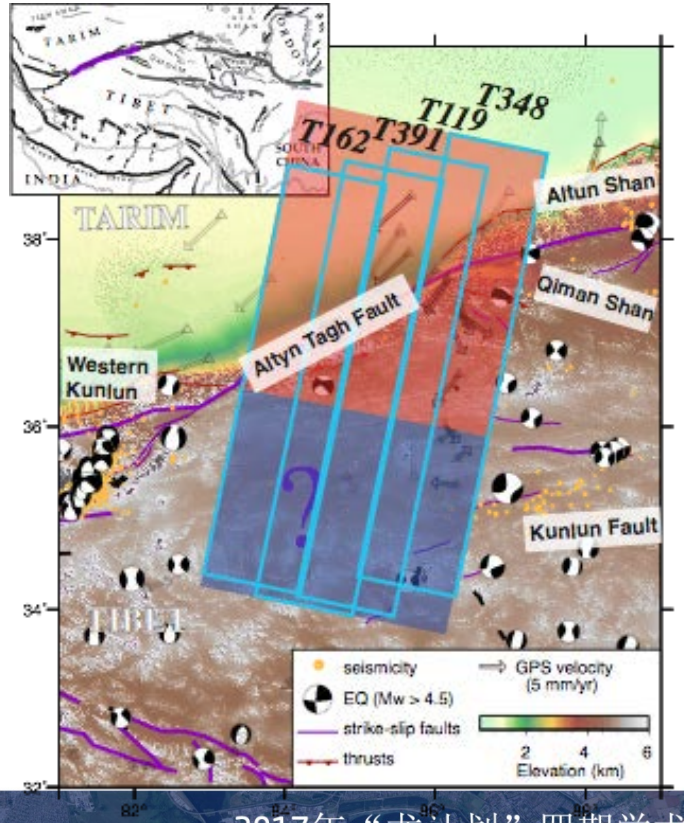


1 – Slip partitioning in NW China, from Envisat InSAR time series

- MAIN CHALLENGES :

Seasonal variations due to freeze and thaw cycles of the permafrost active layer

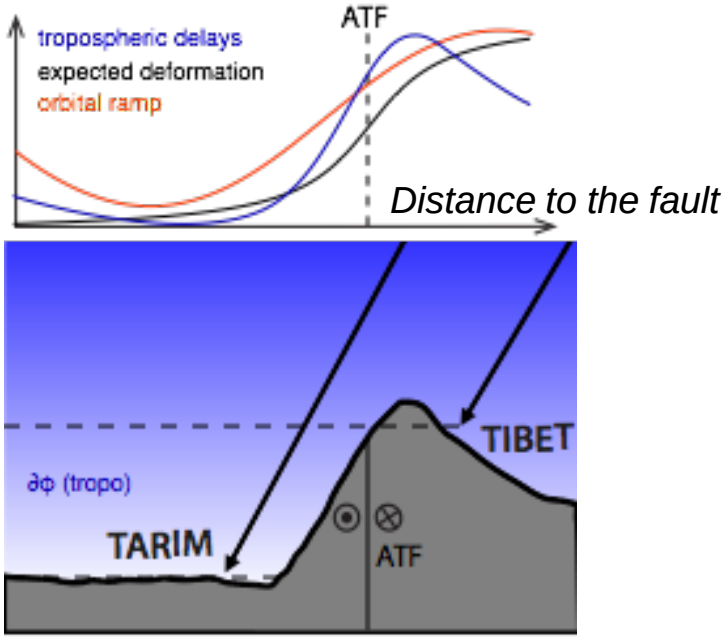


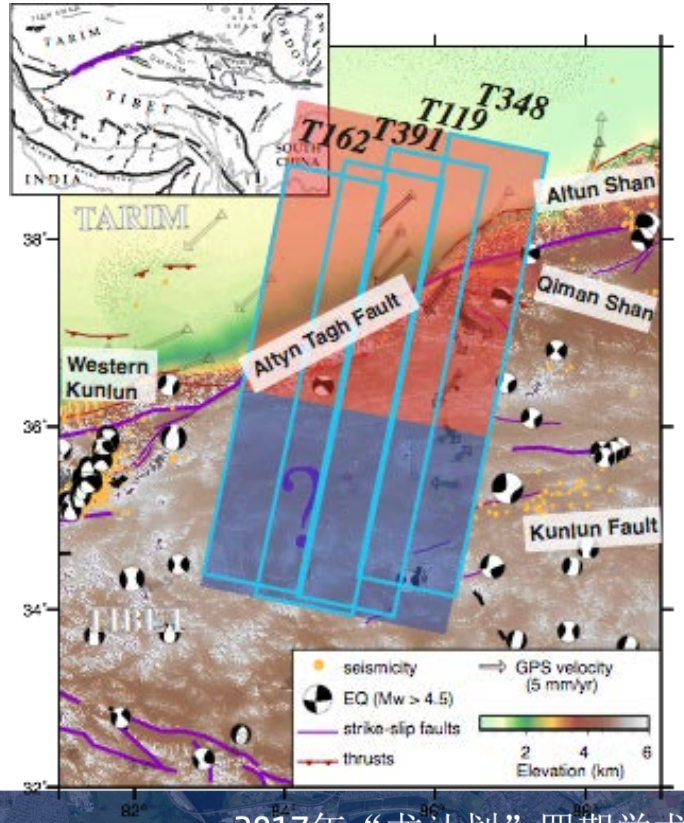


1 – Slip partitioning in NW China, from Envisat InSAR time series

- MAIN CHALLENGES :

Tropospheric delays





1 – Slip partitioning in NW China, from Envisat InSAR time series

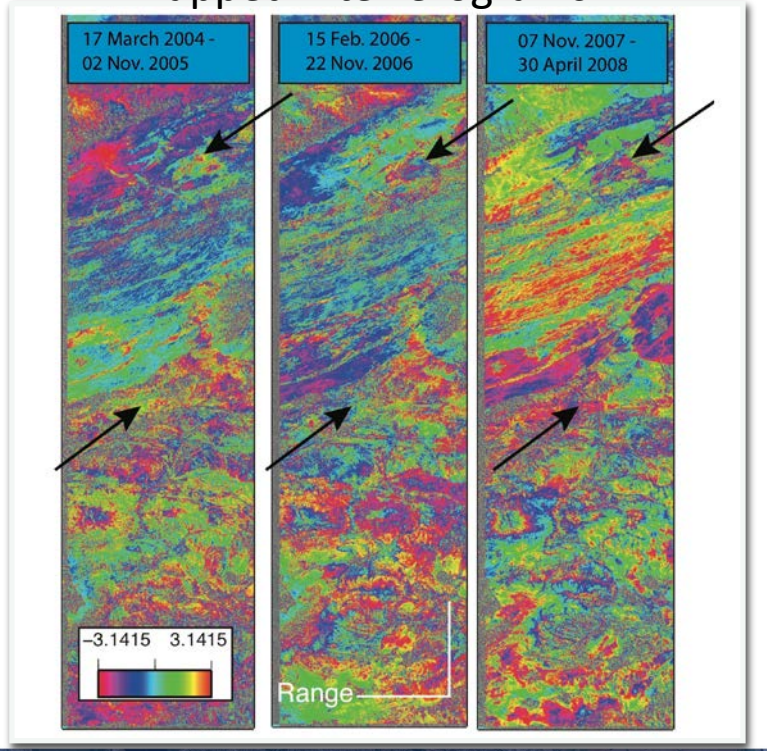
- PERMAFROST SIGNAL :

Local patterns of deformation altering phase continuity (thus unwrapping)

Within the tibetan plateau

Enhanced between winter and summer acquisitions

Wrapped interferograms

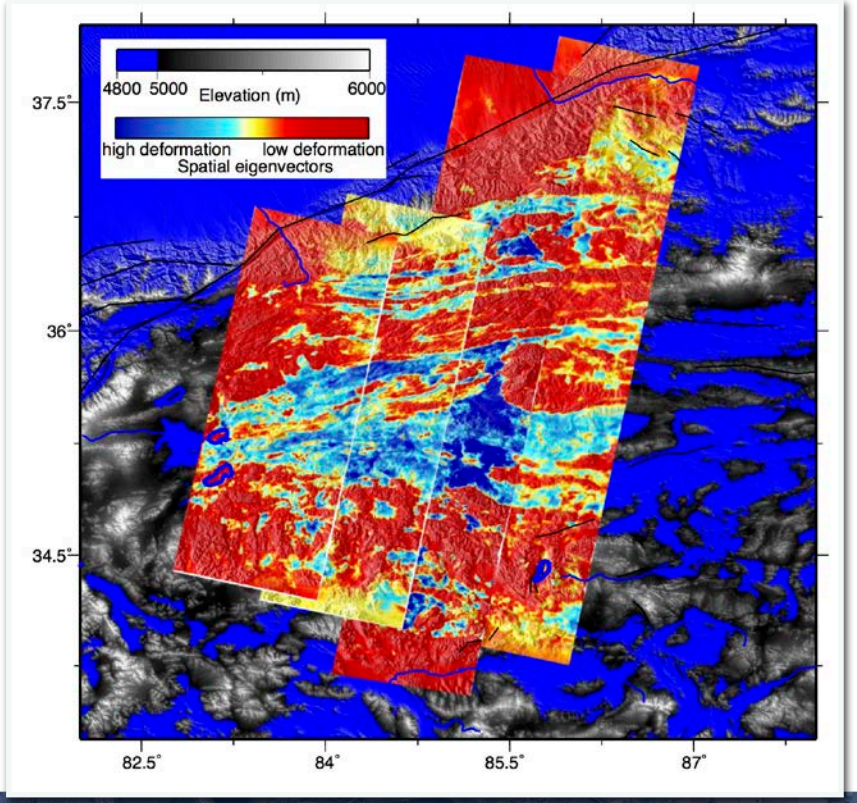


1 – Slip partitioning in NW China, from Envisat InSAR time series

- PERMAFROST SIGNAL :

➢ Step 1 :Principal component analysis of a 1st set of unwrapped interferograms

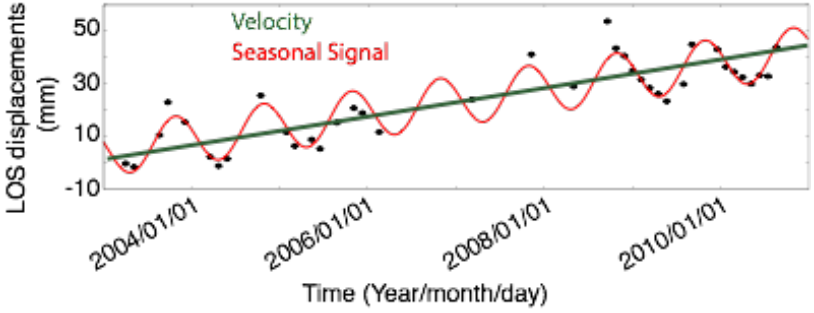
The spatial pattern associated with seasonal variations can be used as a template to unwrap all other individual interferograms

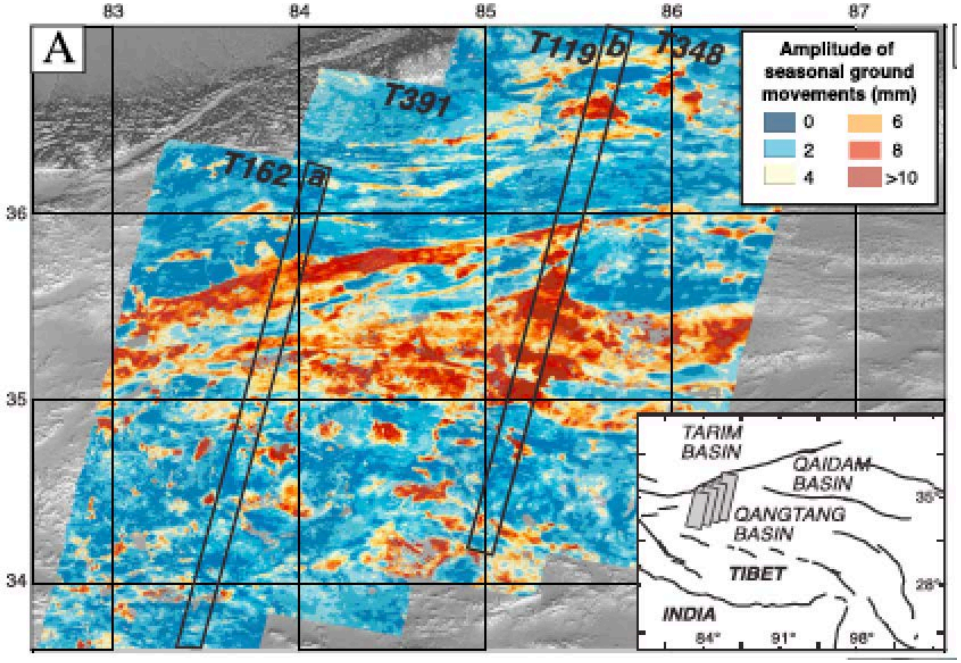


1 – Slip partitioning in NW China, from Envisat InSAR time series

- PERMAFROST SIGNAL :

➢ Step 2 : Time series analysis of the deformation, separating the linear and seasonal term





(Daout et al., 2017)

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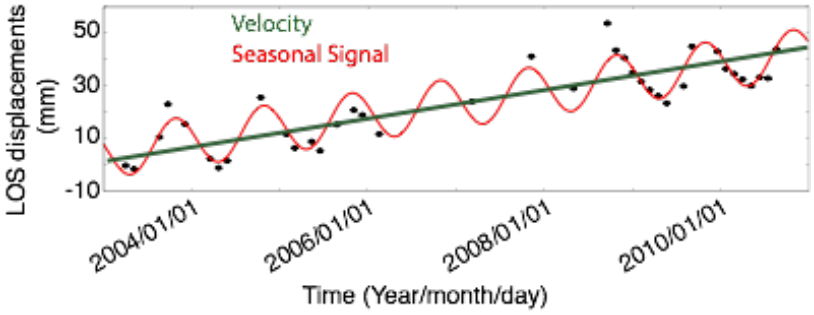
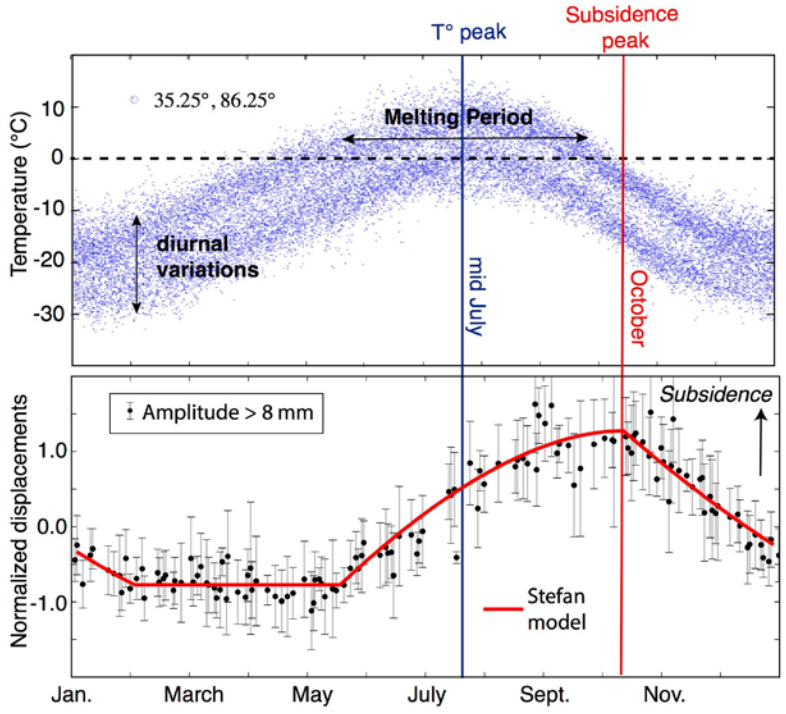




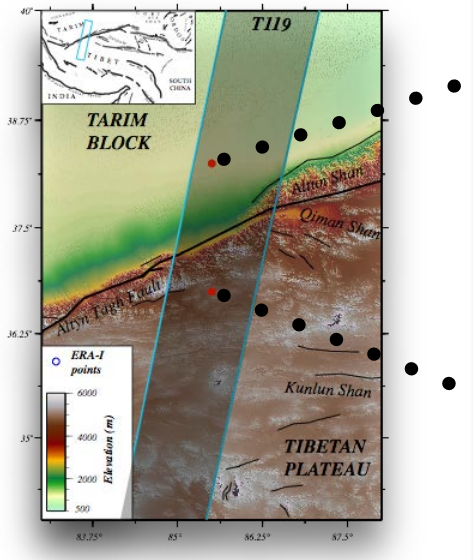
(Daout et al., 2017)

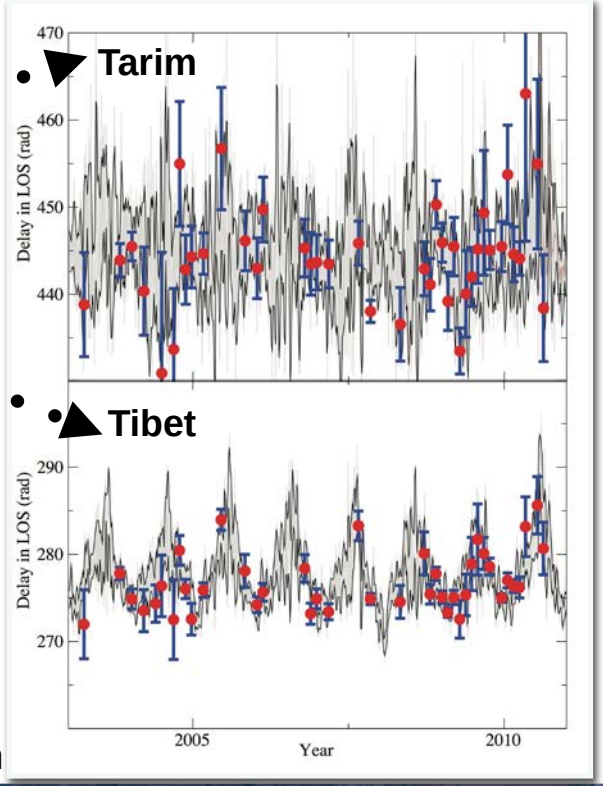
1 – Slip partitioning in NW China, from Envisat InSAR time series

- TROPOSPHERIC SIGNAL :

➢ Corrections made from ERA-Interim model (Jolivet et al., 2011)

➢ Uncertainty related to daily variations taken as a proxy to tropospheric delays corrections





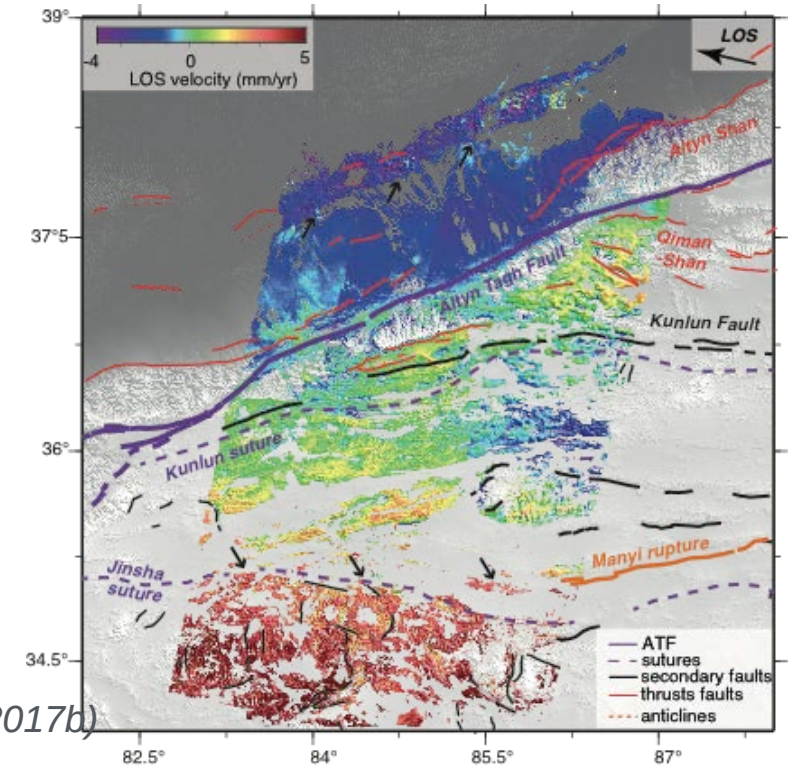
Daily prediction

1 – Slip partitioning in NW China, from Envisat InSAR time series

- TECTONIC SIGNAL :

➢ Time series analysis on bedrock only

➢ Proxy to tropospheric delays corrections used as weight in temporal decomposition



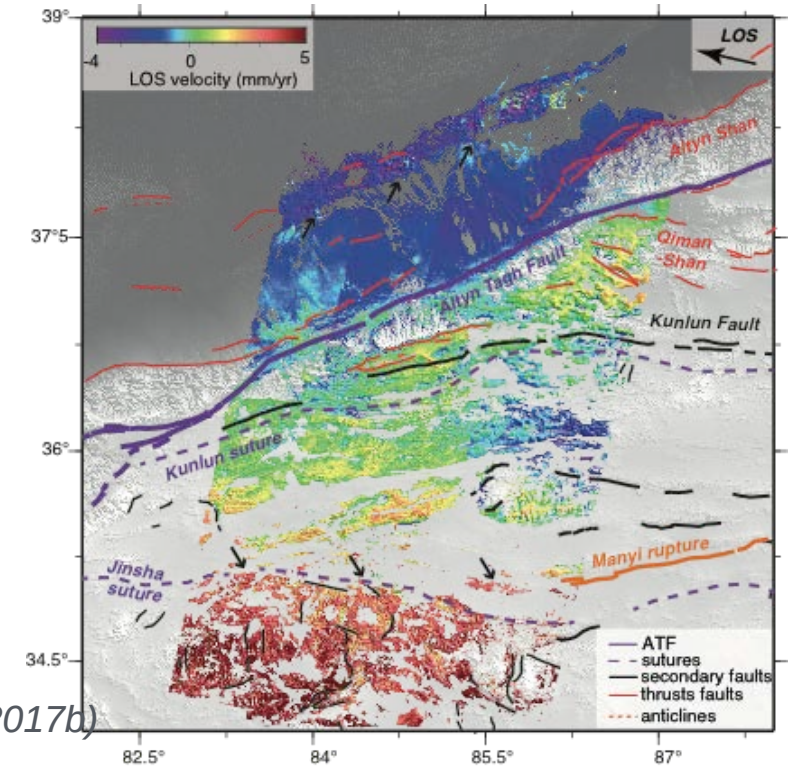
(Daout et al., in prep., 2017b)

1 – Slip partitioning in NW China, from Envisat InSAR time series

- TECTONIC SIGNAL :

3-4 mm/yr of LOS relative velocity between both sides of the fault

4-5 mm/yr of LOS relative velocity between both sides of the Jinsha suture zone => ???



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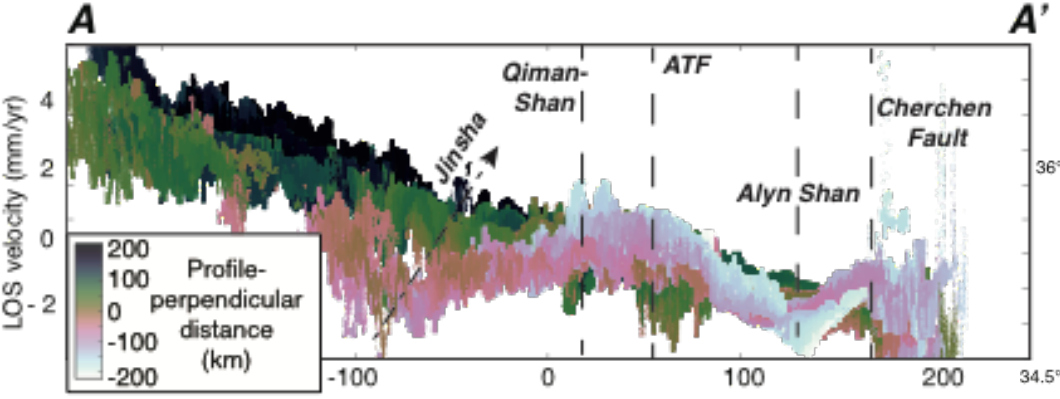
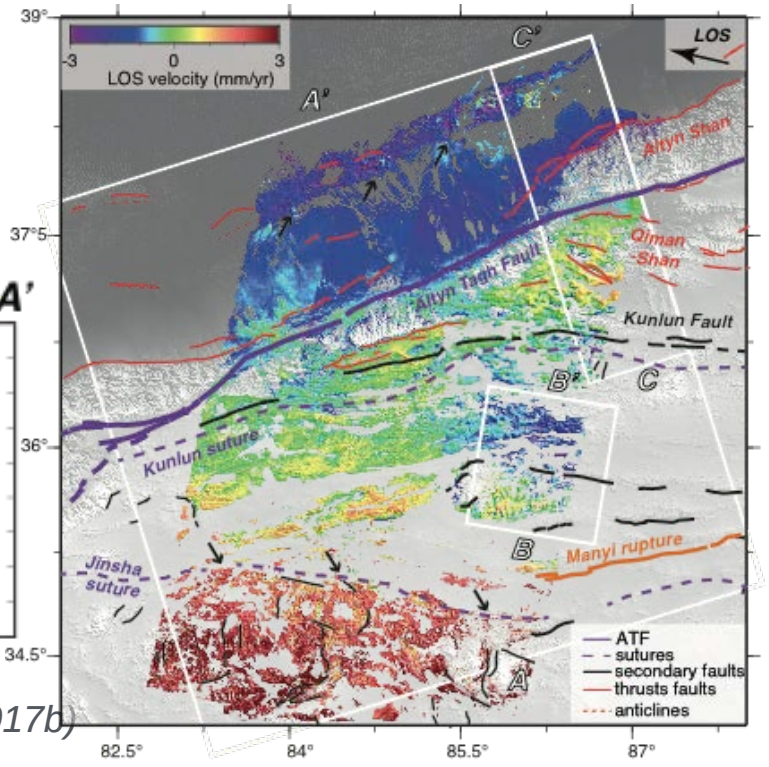




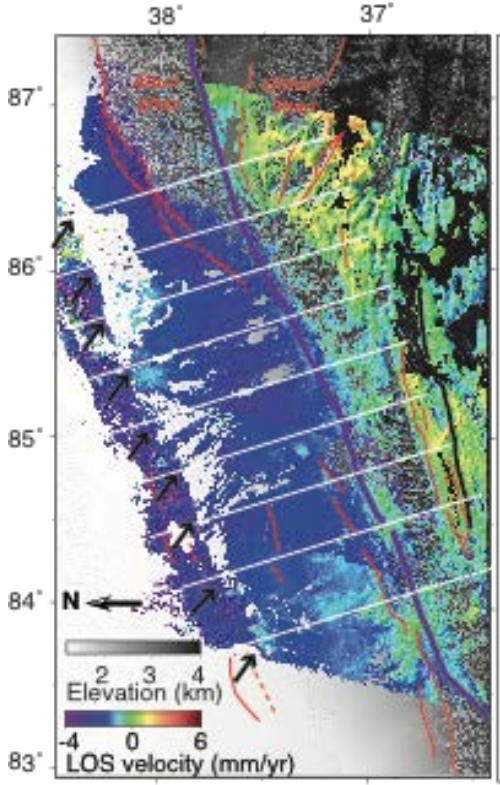
(Daout et al., in prep., 2017b)

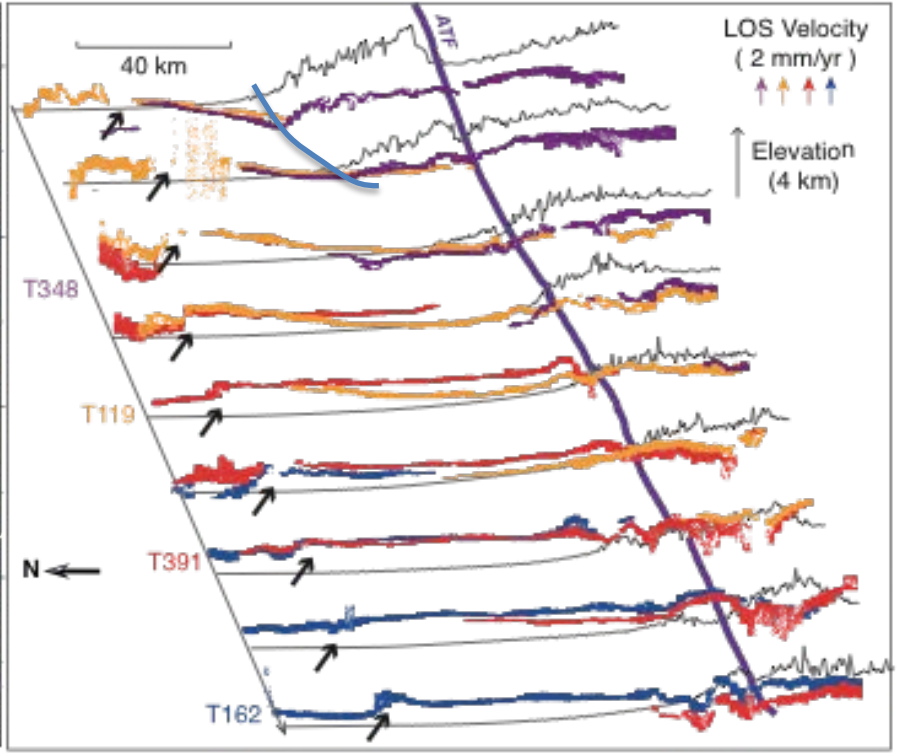
1 – Slip partitioning in NW China, from Envisat InSAR time series

- TECTONIC SIGNAL :

Uplift in the Tarim basin

on a thrust ramp system ?





(Daout et al., in prep., 2017b)

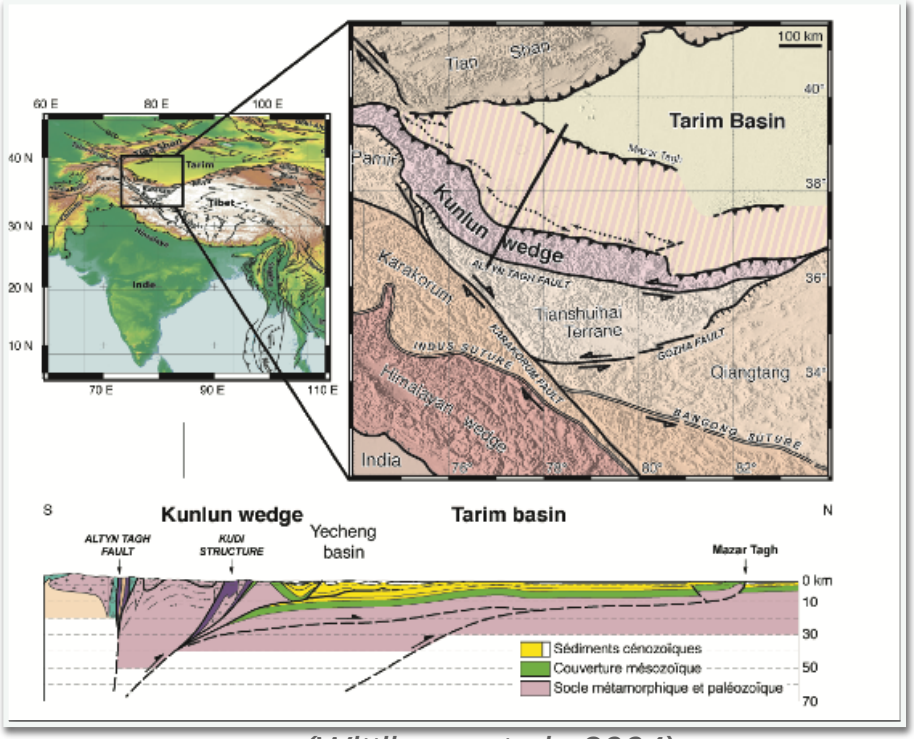
1 – Slip partitioning in NW China, from Envisat InSAR time series

- TECTONIC SIGNAL :

Uplift in the Tarim basin

on a thrust ramp system …

… similar to that observed westward



(Wittlinger et al., 2004)

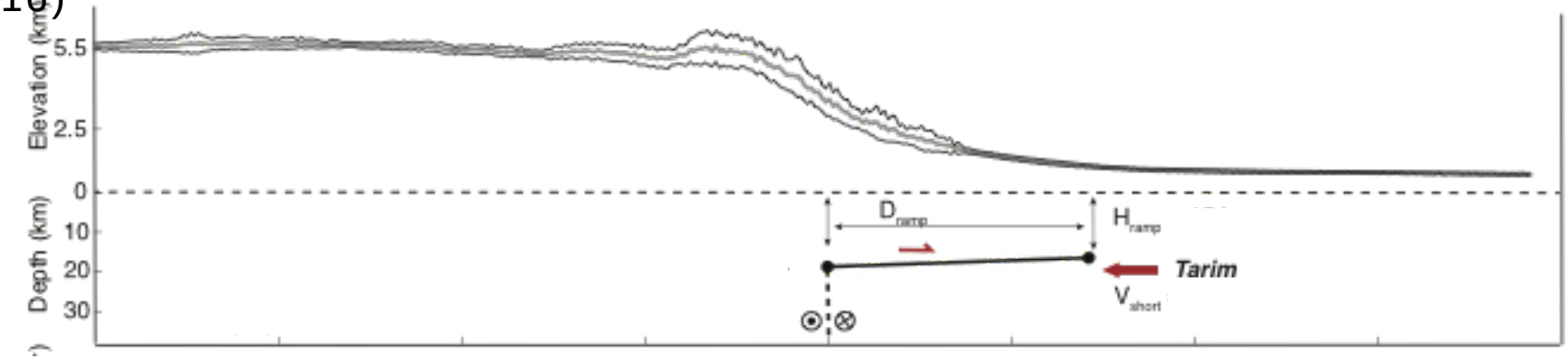
1 – Slip partitioning in NW China, from Envisat InSAR time series

- TECTONIC SIGNAL MODELING :

Vertical left-lateral fault + thrust ramp

Elastic, homogeneous ½ space

Bayesian inversion of left-lateral velocity (V), locking depth (H) and ramp geometry : Protools software (https://github.com/simondaout/protools.git, Daout et al., 2016)



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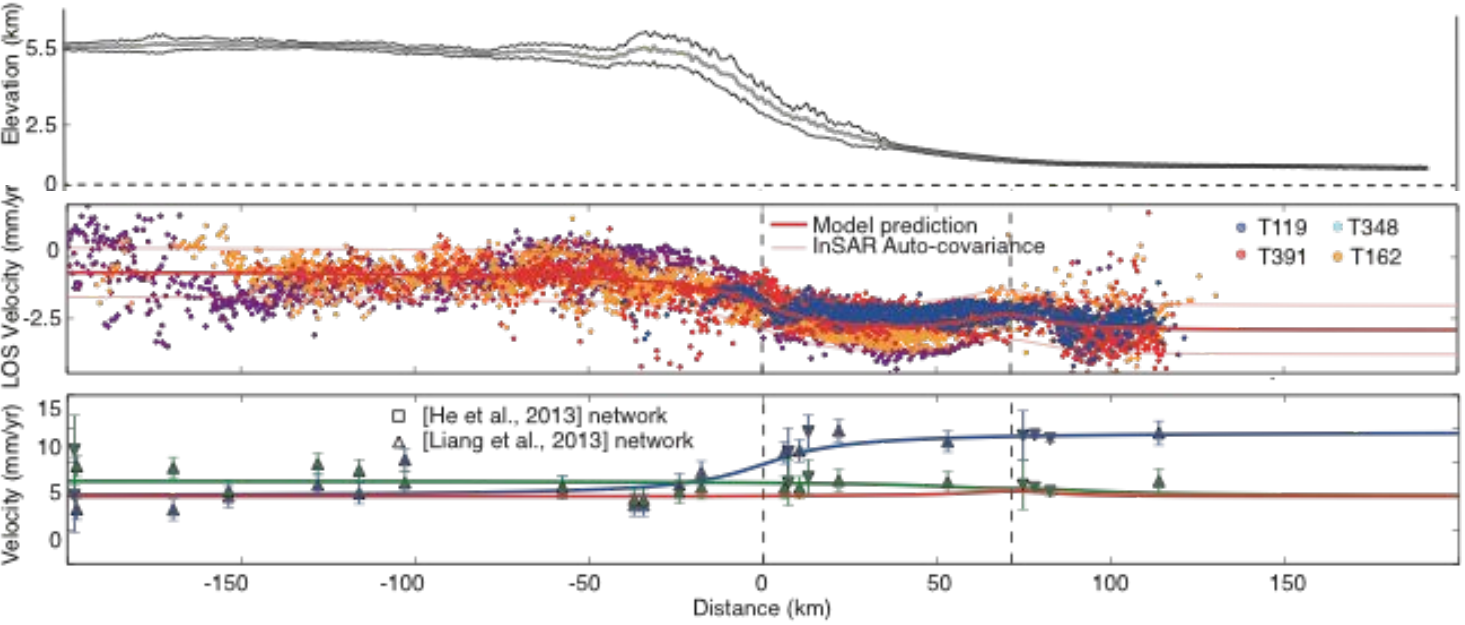
- TECTONIC SIGNAL MODELING :



ATF left-lateral rate :
~ 10 mm/yr

Convergence rate :
~ 3 mm/yr

Part 1 – Main results and perspectives

- When studying tectonic deformation, you may end up / need to study non tectonic deformation !

- It can be interesting : permafrost related deformation can be modeled with unprecedented temporal resolution here, thanks to the long time series of InSAR data. To be continued…

- Multiple view angles of fault-related deformation are required together with 3D fault models to study deformation partitioning at large scale : Sentinel-1 will help making progress.

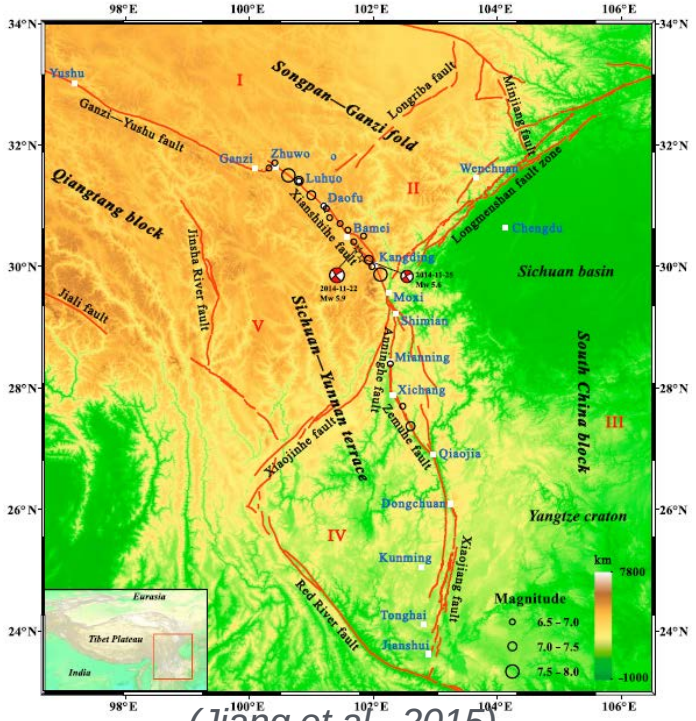
2 - Strain accumulation across the Ganzi fault, from Sentinel-1 InSAR time series

- THE YUSHU-GANZI-XIANSHUIHE FAULT SYSTEM :
  - ~ 1400 km-long
  - 9 M>7 earthquakes since 1725
  - 3 main segments

✧ The Yushu segment :

✧ The Xianshuihe segment :

✧ The Ganzi segment :



(Jiang et al., 2015)

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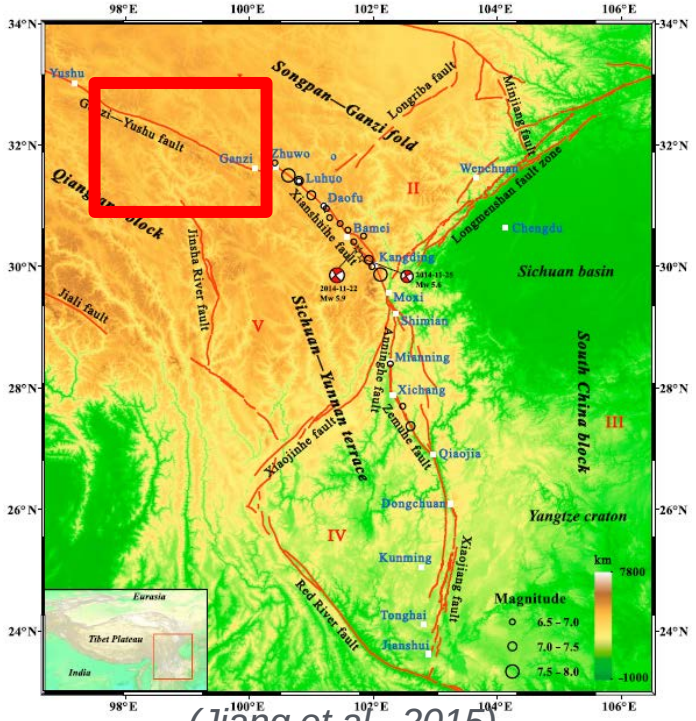

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- THE YUSHU-GANZI-XIANSHUIHE FAULT SYSTEM :
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  - 3 main segments

✧ The Yushu segment :

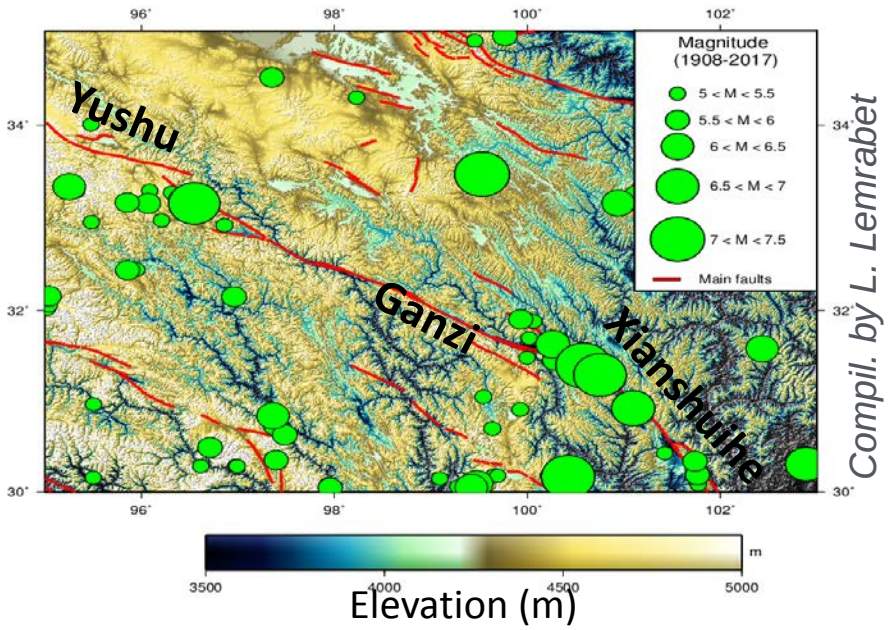
last EQ in 2010 (Mw6.9)

✧ The Xianshuihe segment :

last EQ in 1981 (Mw6.9)

✧ The Ganzi segment :

a 300 km-long seismic gap

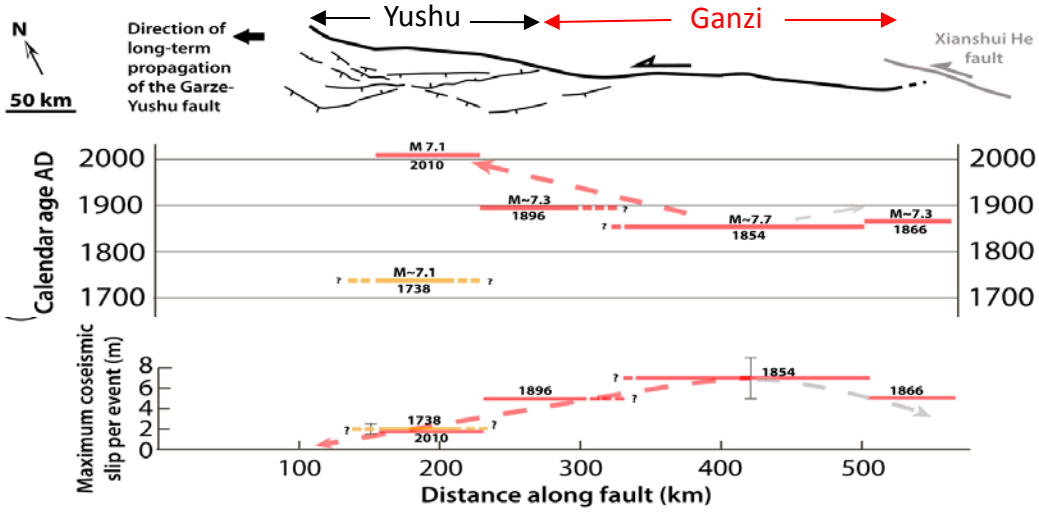


2 - Strain accumulation across the Ganzi fault, from Sentinel-1 InSAR time series

- THE GANZI SEGMENT :

  a 300 km-long seismic gap

  unbroken since 1854 (Mw7.7)



(Perrin et al., 2016)

2 - Strain accumulation across the Ganzi fault, from Sentinel-1 InSAR time series

- THE GANZI SEGMENT :

  a 300 km-long seismic gap

  unbroken since 1854 (Mw7.7)

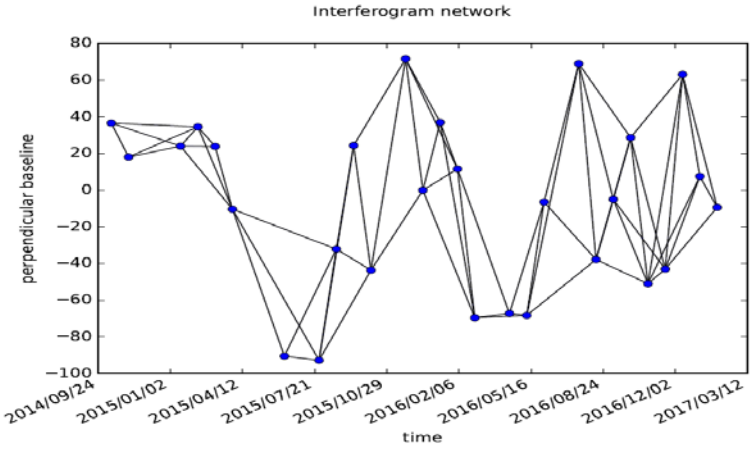
  geological slip-rates : 6-8 mm/yr

(Chevalier et al., 2017)

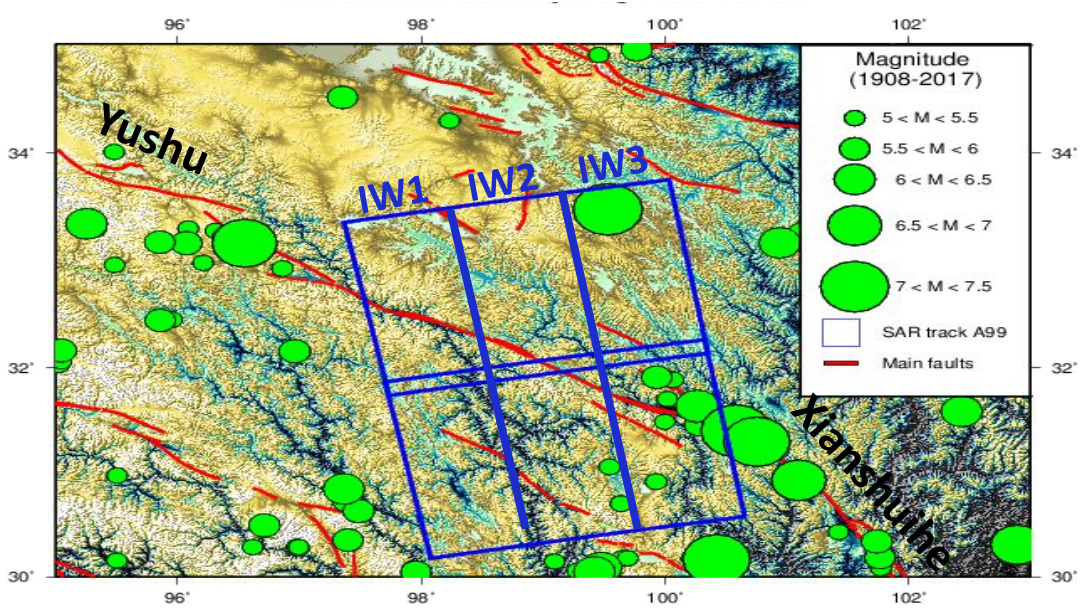
GPS slip-rates : 6-14 mm/yr (e.g. Wang et al., 2017); **InSAR ???**

2 - Strain accumulation across the Ganzi fault, from Sentinel-1 InSAR time series

- SENTINEL-1 DATA SET :



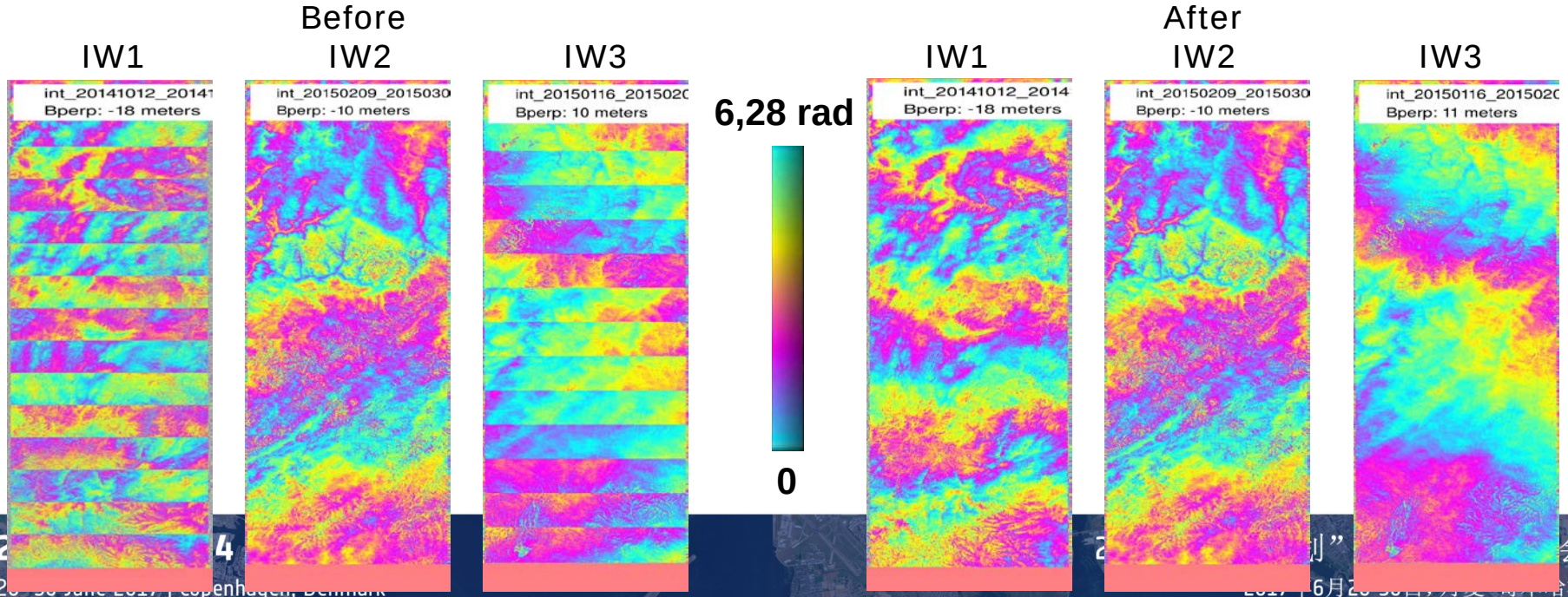
Ascending track 99
28 images until March 2017



Elevation (m)

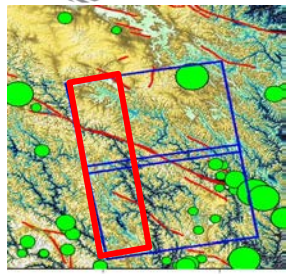
2 - Strain accumulation across the Ganzi fault, from Sentinel-1 InSAR time series

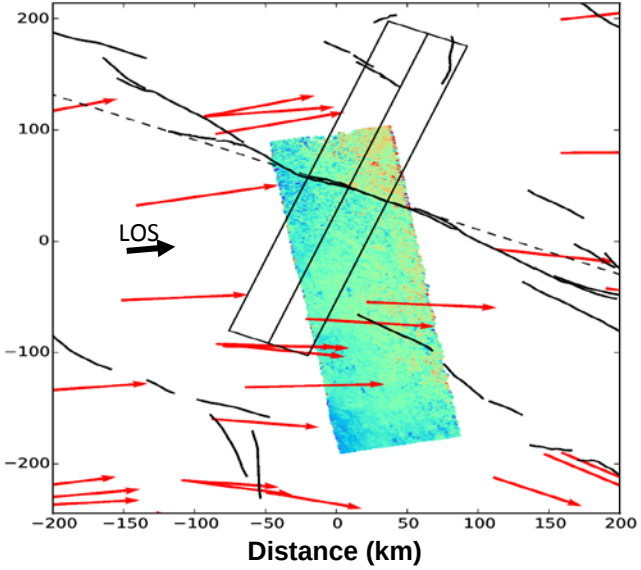
- PROCESSING : NSBAS (Grandin, 2015)
- EXAMPLES OF INTERFEROGRAMS : before/after correction of spectral diversity

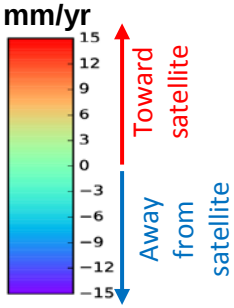


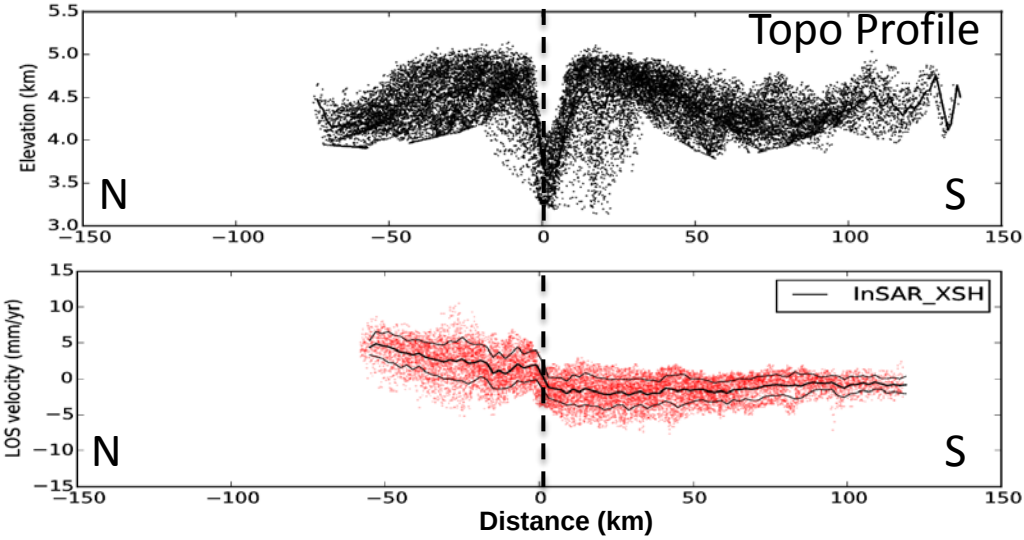
2 - Strain accumulation across the Ganzi fault, from Sentinel-1 InSAR time series

- TIME SERIES ANALYSIS: IW1



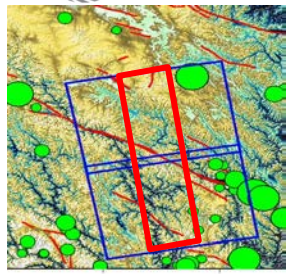


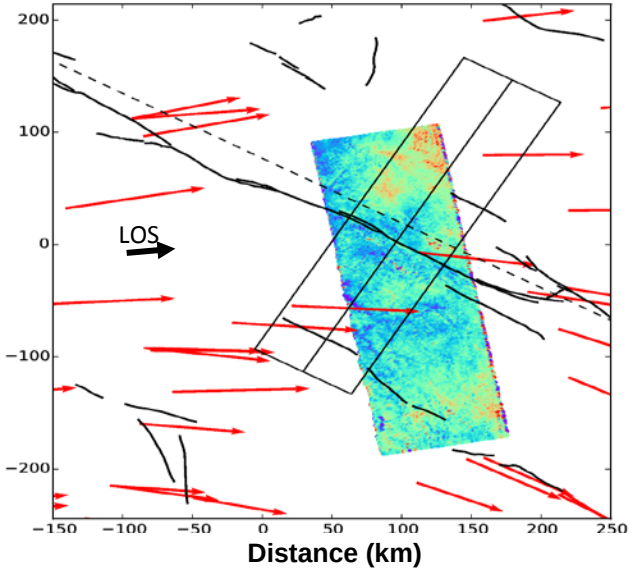


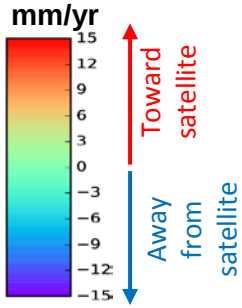


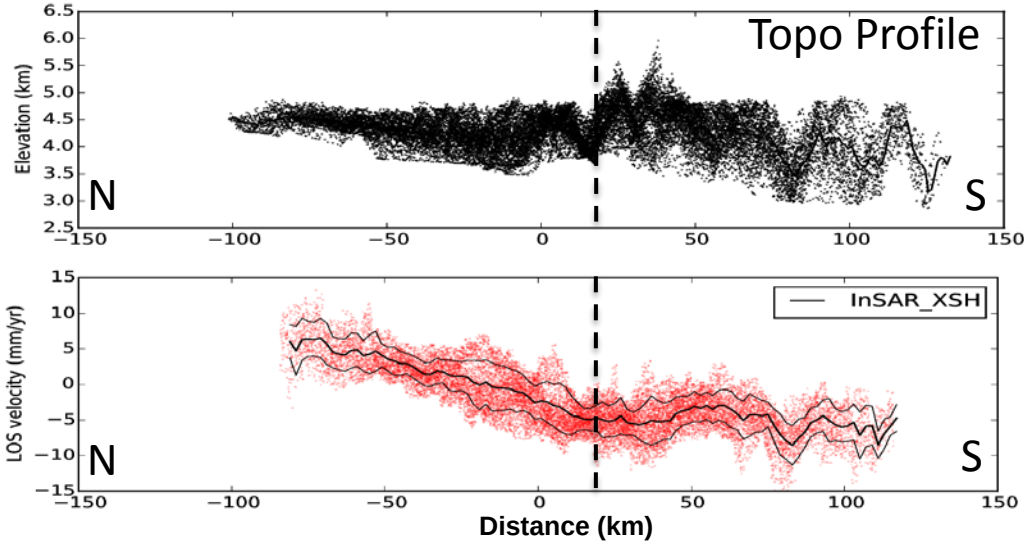
2 - Strain accumulation across the Ganzi fault, from Sentinel-1 InSAR time series

- TIME SERIES ANALYSIS: IW2









2 - Strain accumulation across the Ganzi fault, from Sentinel-1 InSAR time series

- PRELIMINARY MODELS :

Vertical left-lateral fault with fixed location

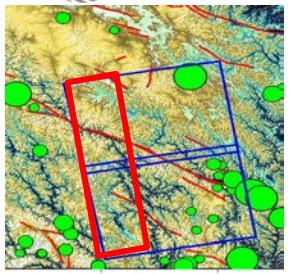
Elastic, homogeneous ½ space

Bayesian inversion of fault velocity (V) and locking depth (H) :

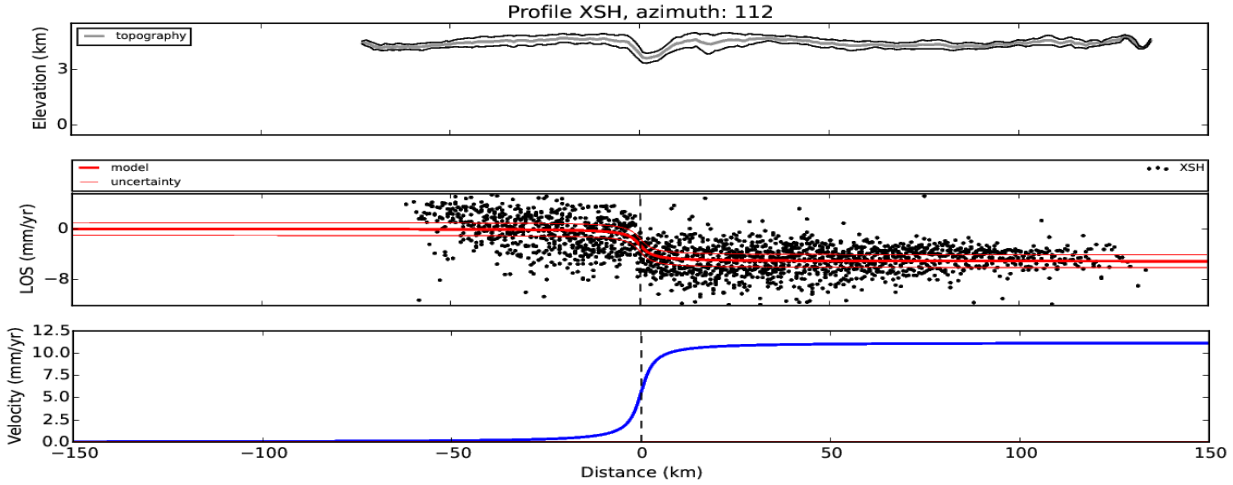
Protools software (https://github.com/simondaout/protools.git, Daout et al., 2016)

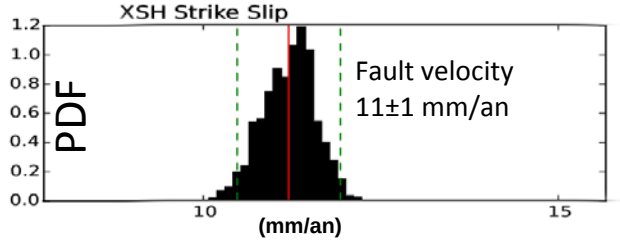
A priori model : Uniform distribution of V (0-20 mm/yr) and H (0-30 km)

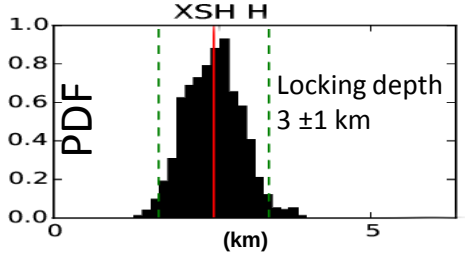
2 - Strain accumulation across the Ganzi fault, from Sentinel-1 InSAR time series



- PRELIMINARY MODELS : IW1

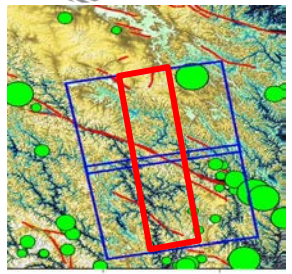




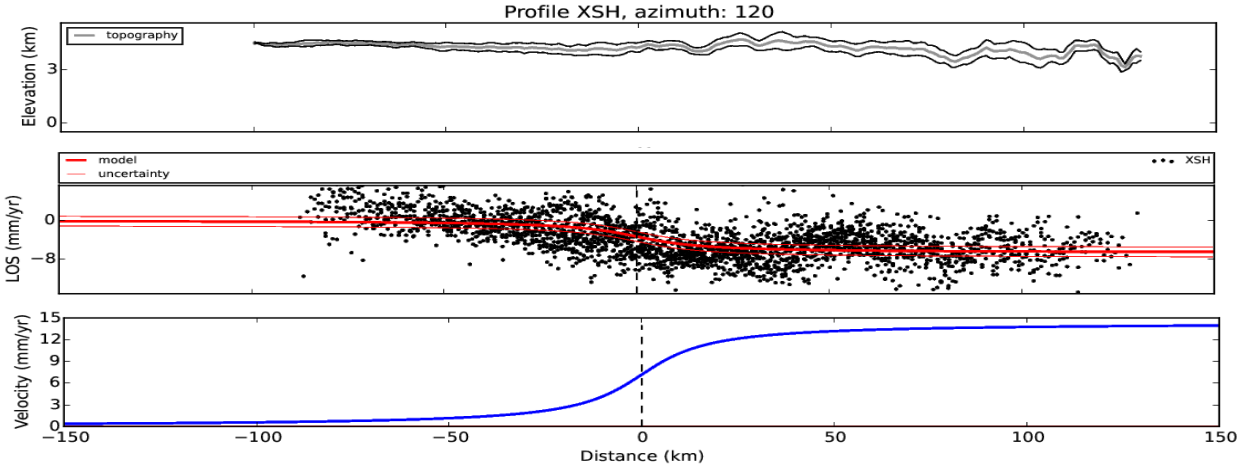


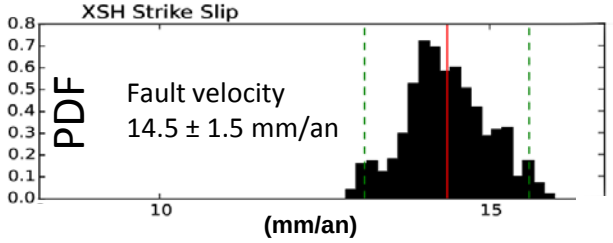
CREEP ???

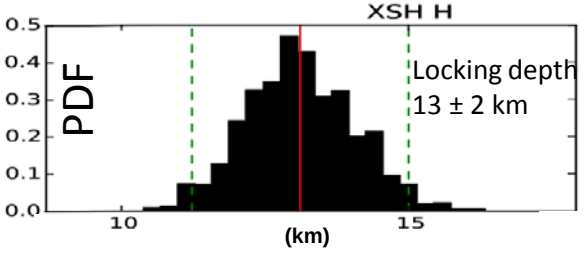
2 - Strain accumulation across the Ganzi fault, from Sentinel-1 InSAR time series



- PRELIMINARY MODELS : IW2

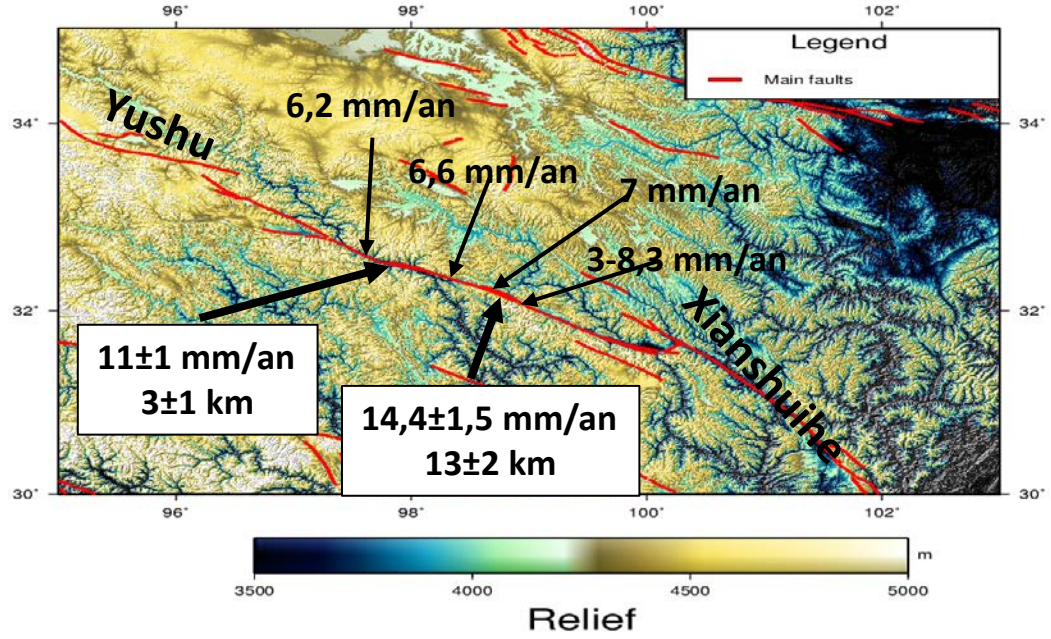






2 - Strain accumulation across the Ganzi fault, from Sentinel-1 InSAR time series

- COMPARISON WITH CHEVALIER ET AL., 2017 :



Part 2 – Main results and perspectives

- With less than 3 years of Sentinel-1 data we were able to retreive the strain accumulation pattern across the Ganzi fault segment

- The study reveals intriguing, along-strike variations of the deformation localisation, with creep likely occurring near the junction between the Yushu and Ganzi segments. To be further investigated…

- Both ascending and descending data processing will be completed across this fault before moving on to larger scale fault studies.