École et observatoire des **sciences de la Terre** de l'Université de Strasbourg et du CNRS

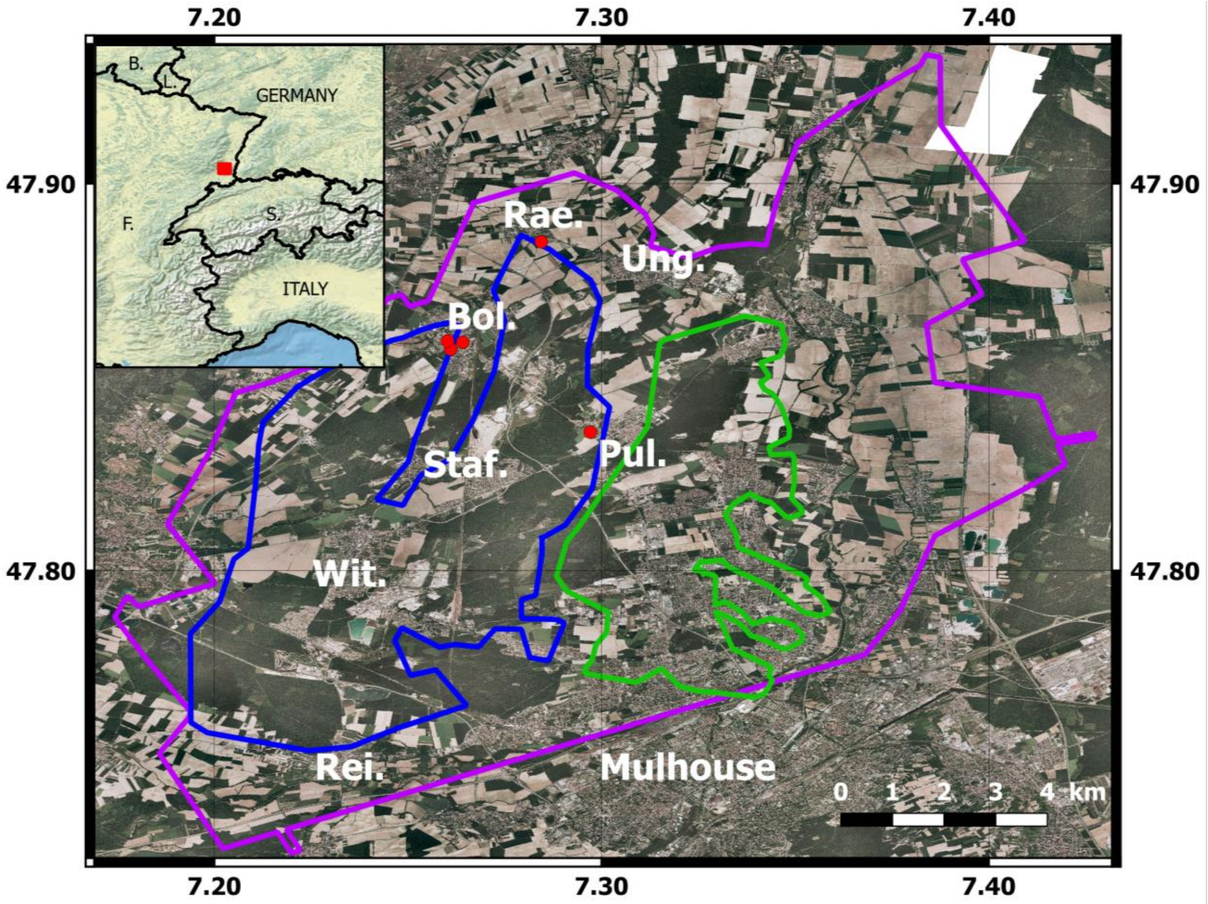
Mining subsidence detection by remote measurements over the MDPA

Guillaume Modeste, Cécile Doubre and Frédéric Masson

Mines Domaniales de Potasse d'Alsace (MDPA)

- North-East France, in the Upper Rhine Graben
- Extraction from 1910 to 2002
- Mined area ~ 200 km²
- Two layers located between 400 m (South) and 1 100 m (North) deep

- the shallowest: 1-2 m
- the deepest: 1-5,5m



Map of the MDPA's concessions with the two exploited sectors.

Mining subsidence

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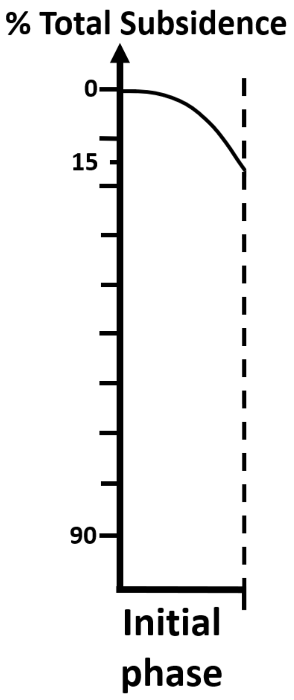
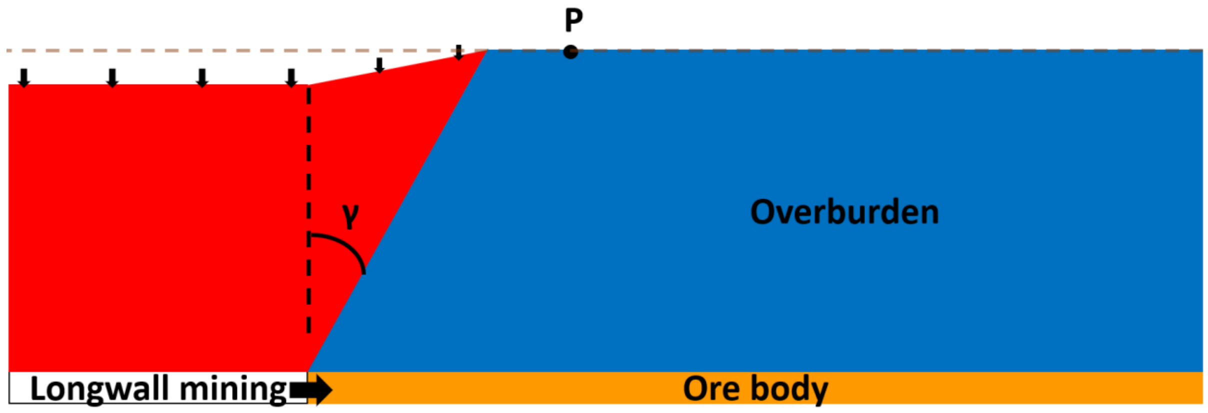
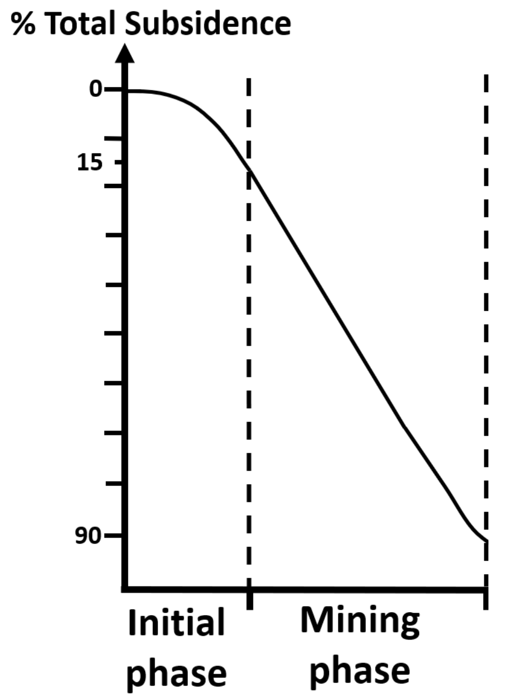
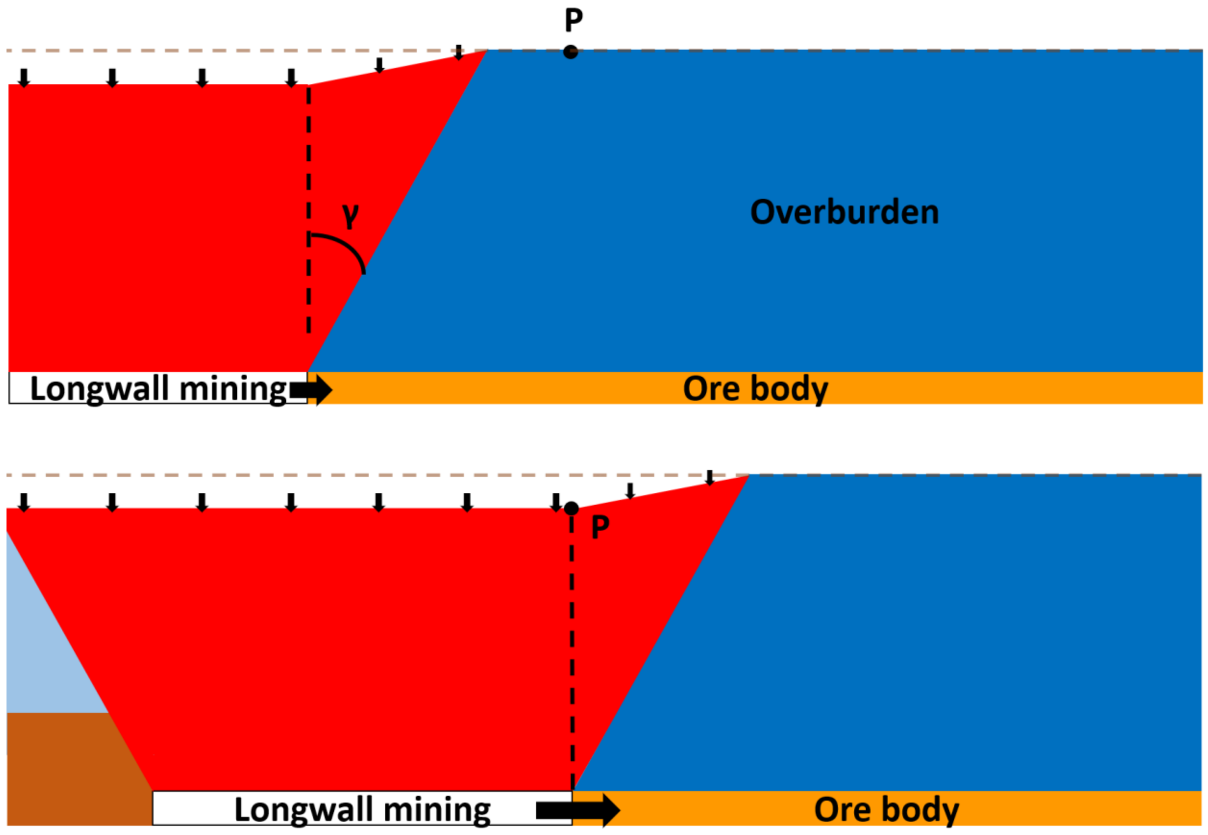




- MDPA's estimations :
- Angle of draw: ~35°

Mining subsidence





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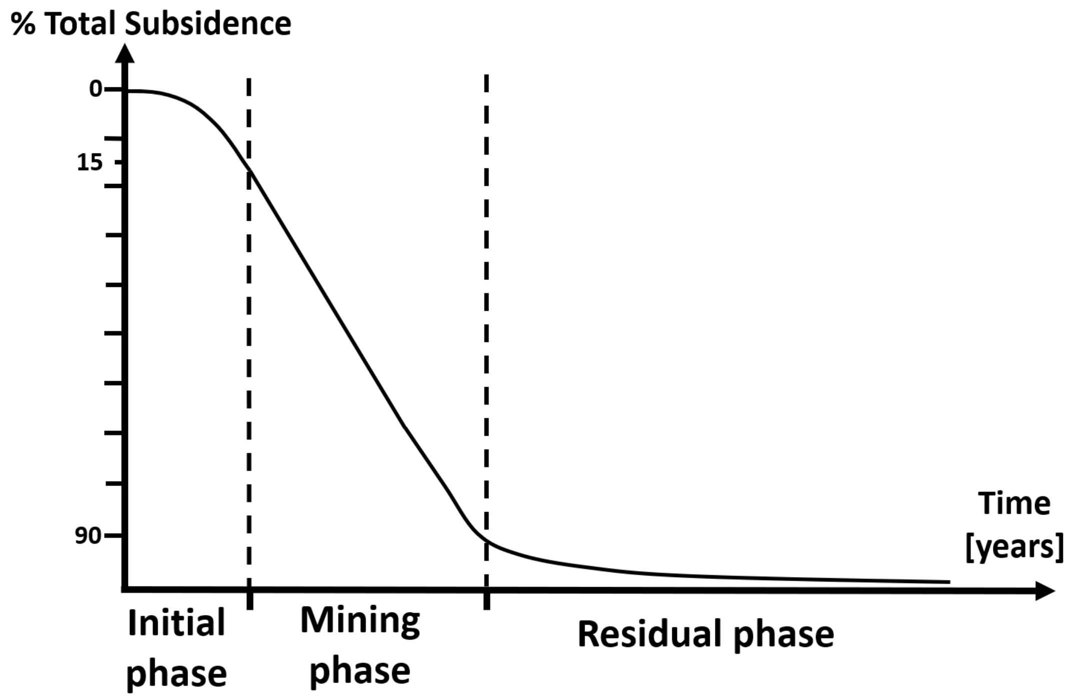
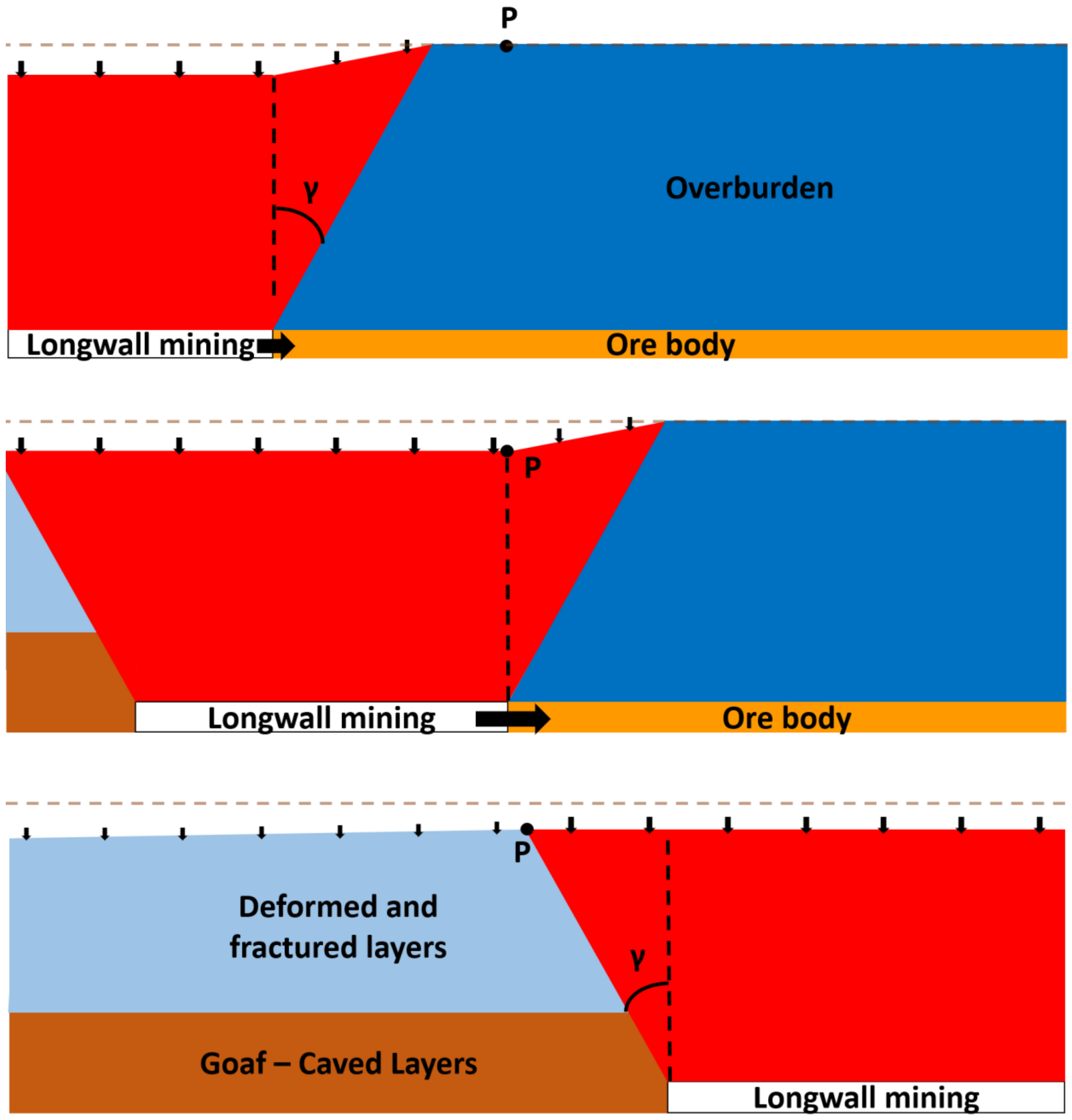


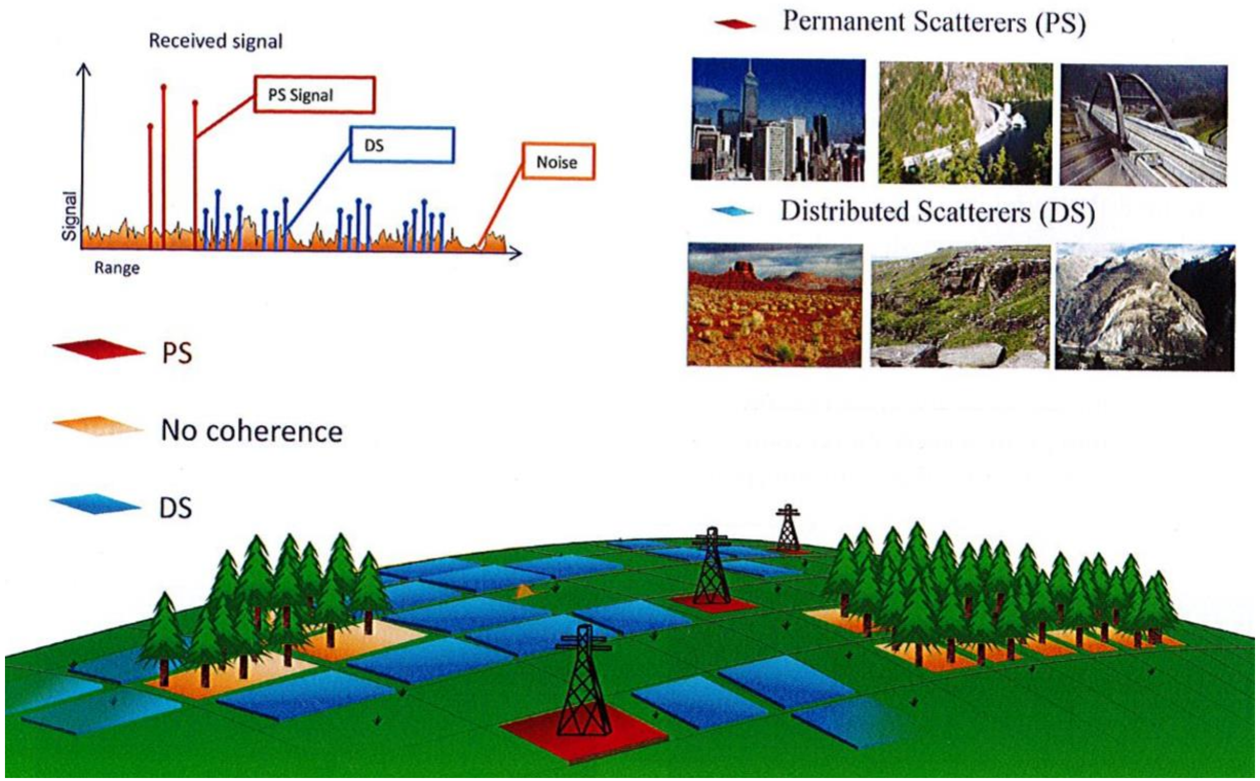


- MDPA's estimations :
- Angle of draw: ~35°
- Residual subsidence: ~10% of the total subsidence

Can we detect, monitor and characterize mining subsidence over the MDPA with InSAR ?

InSAR processing

- High temporal and spatial decorrelations expected with low coherence areas
- Use of the Persistent Scatterers
- Software: StaMPS (Hooper et al., 2012)

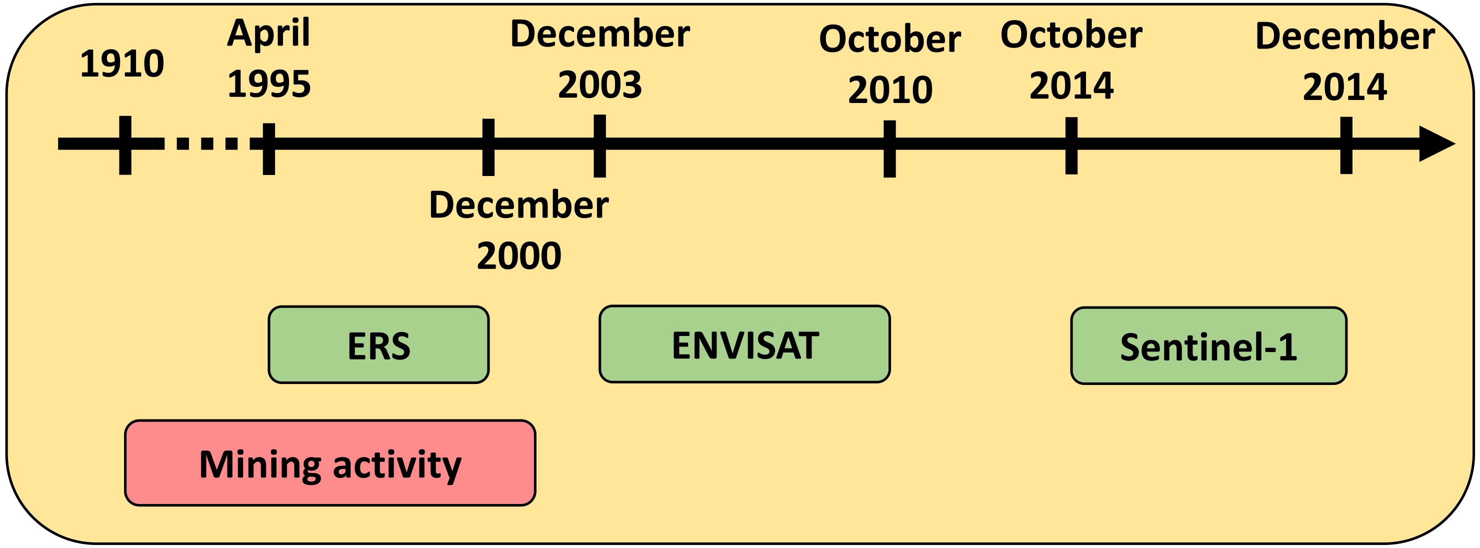


Permanent/Persistent Scatterers (Feretti, 2014).

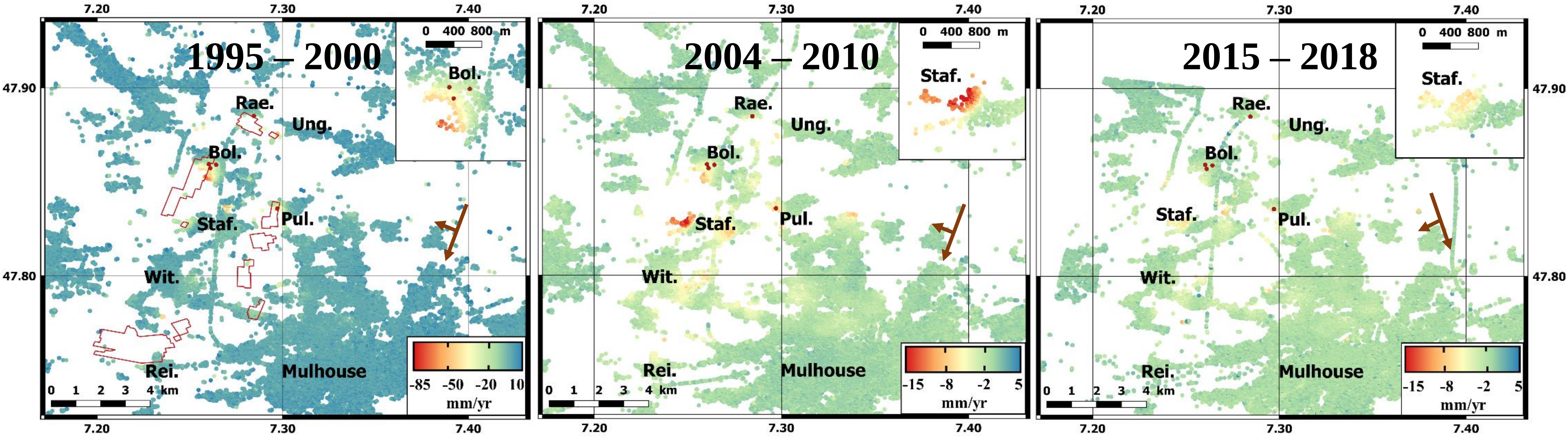
SAR archives

- 3 different satellites
- Complementary observation
- Both ascending and descending tracks available
- Enough data to complete processing
- Results from the richest track

Satellite	Acquisition period [d]	Number of track	Workable track	Mean images number
ERS	35	4	3	43
ENVISAT	35	4	4	33
Sentinel-1	12 - 6	2	2	>100



Mean LOS velocity map



ERS

ENVISAT

Sentinel-1

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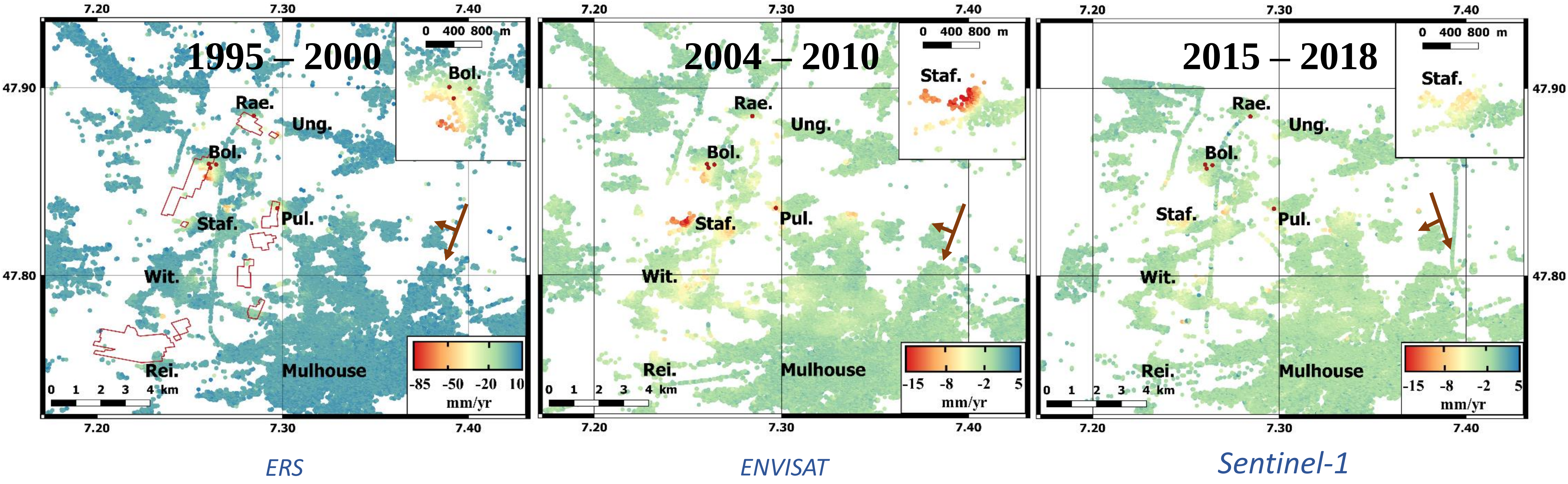
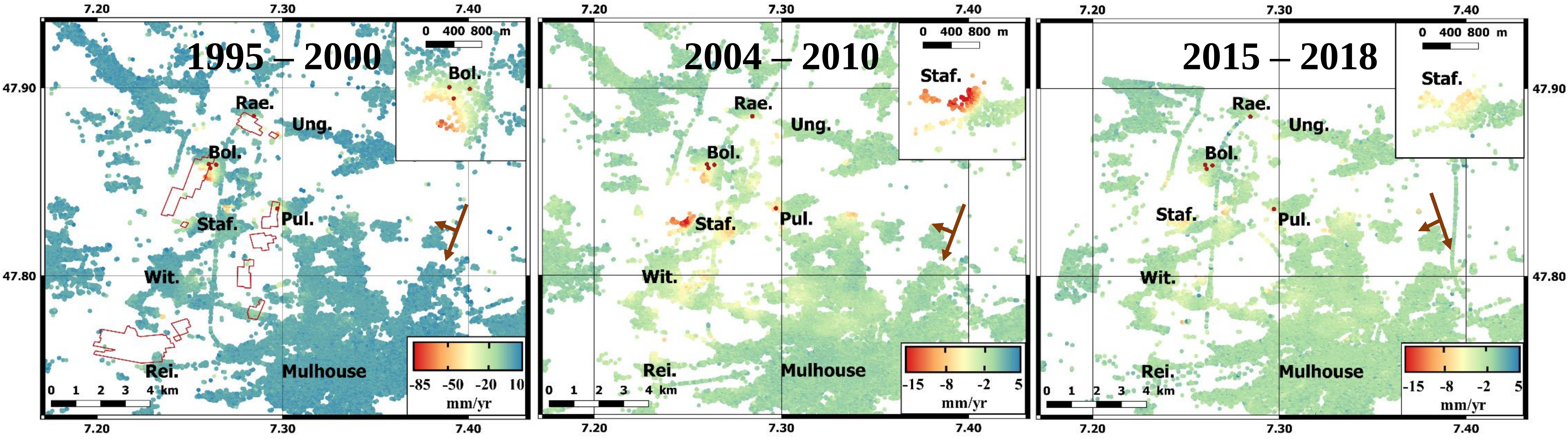


- Localised deformation (<1km²)

Mean LOS velocity map



ERS *ENVISAT* *Sentinel-1*

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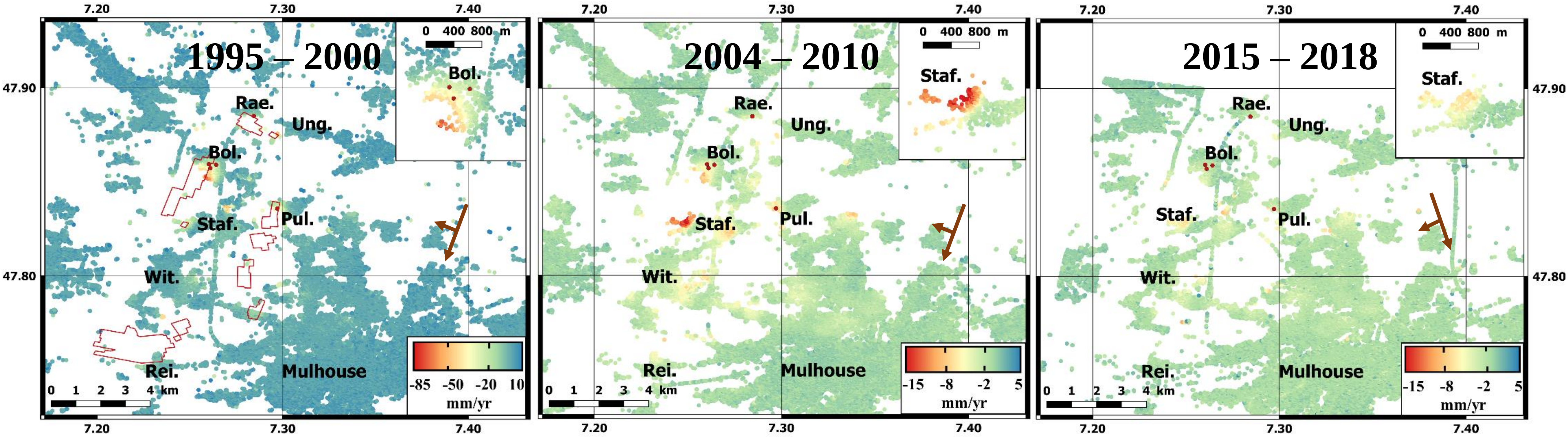
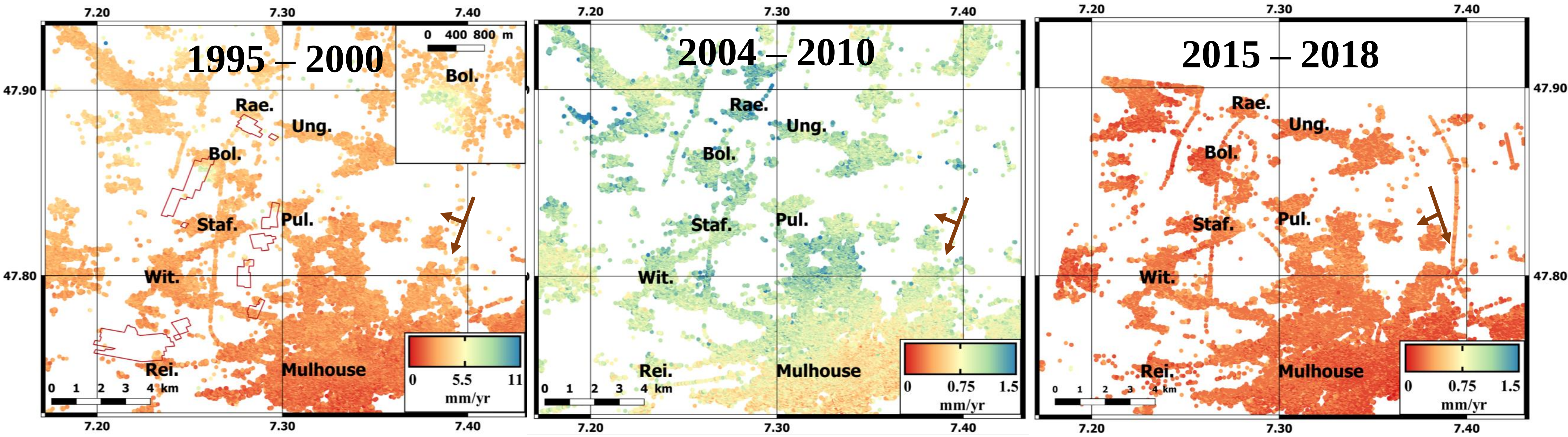


ERS *ENVISAT* *Sentinel-1*

- Localised deformation (<1km²)
- Decreasing rate after the end of activity
- Deformation occurring 13 years after

Standard deviation map



ERS ENVISAT *Sentinel-1*

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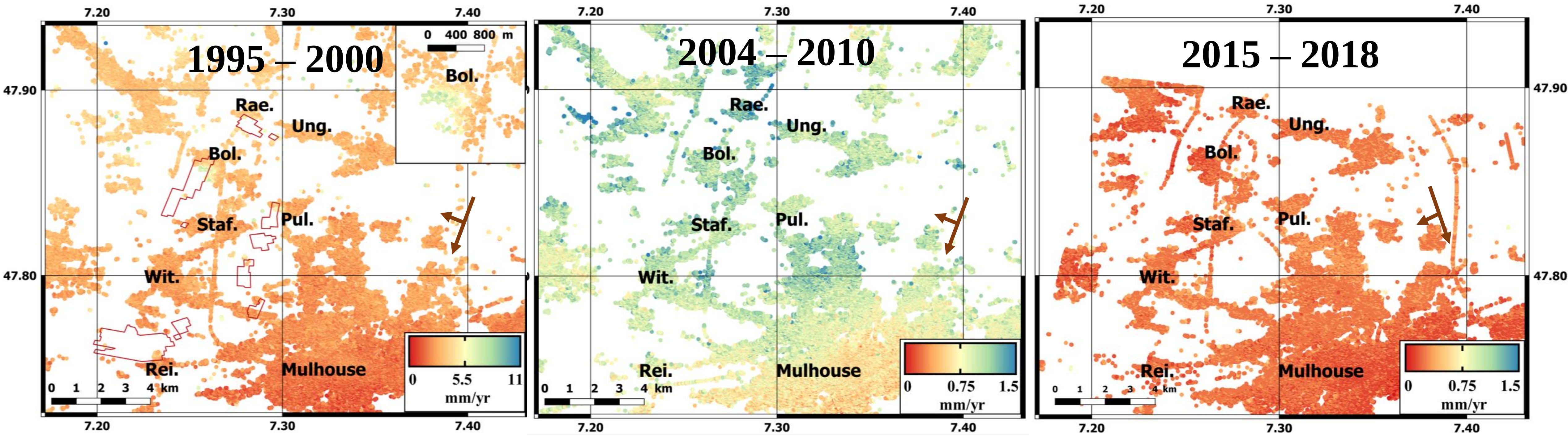

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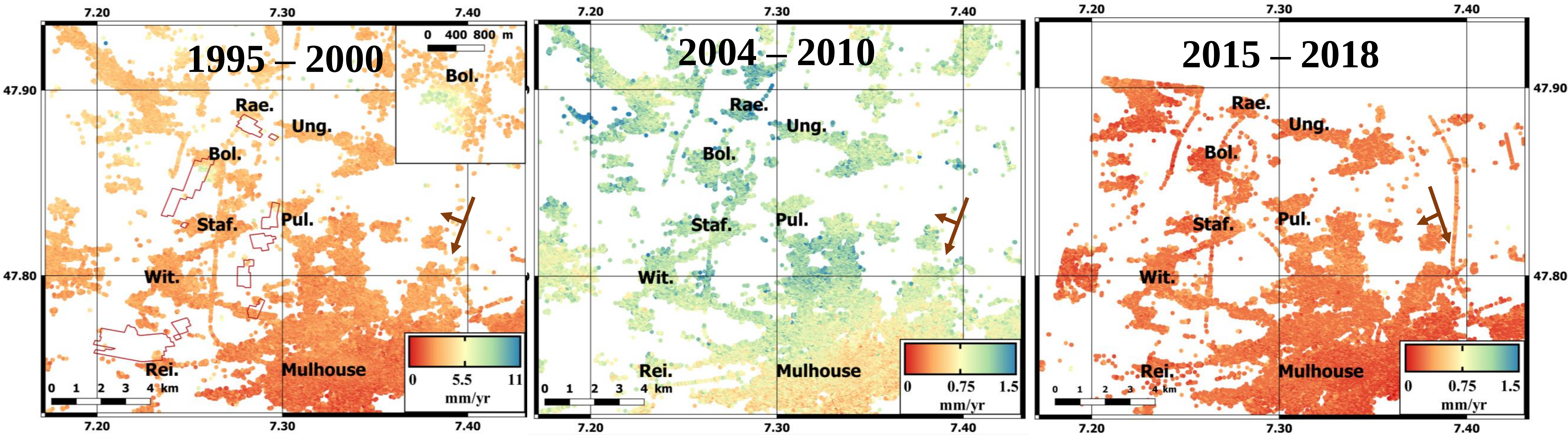
- High localised standard deviation over the ERS period (exploitation phase)

Standard deviation map

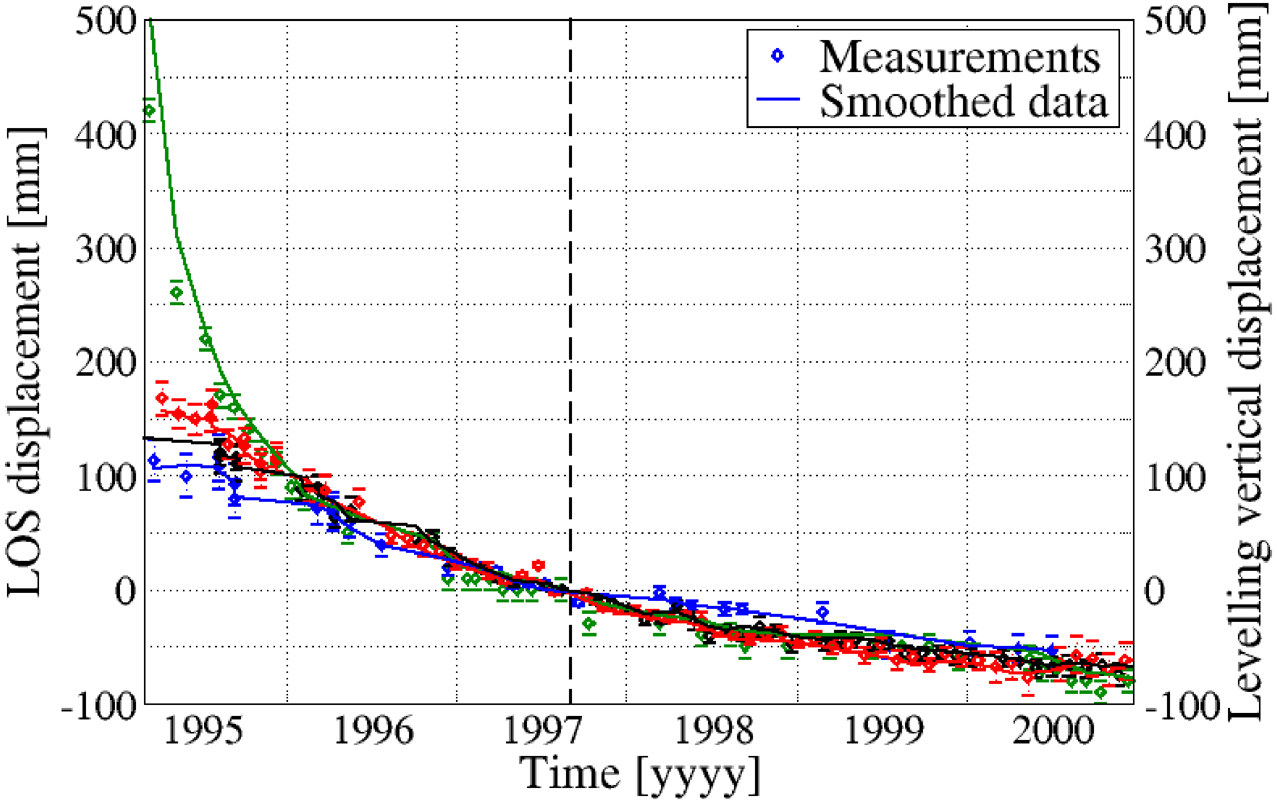


ERS *ENVISAT* *Sentinel-1*

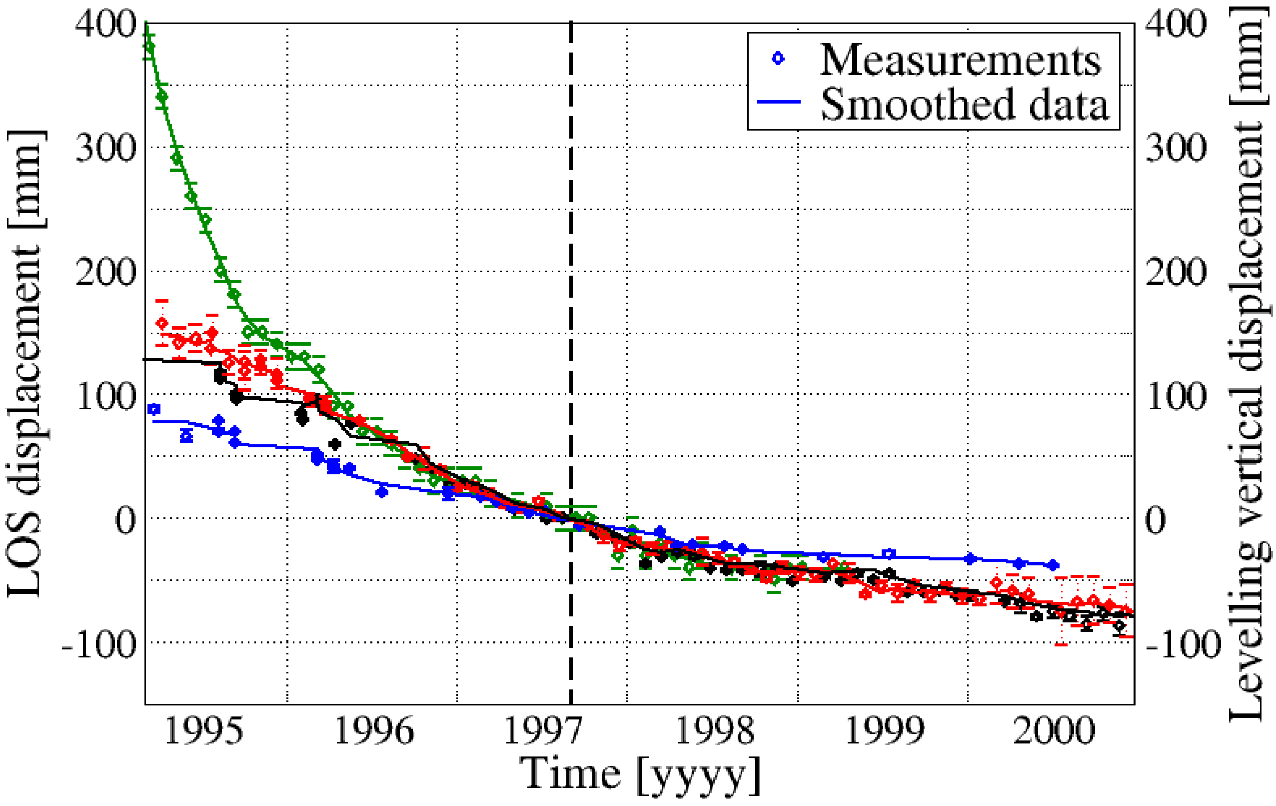
- High localised standard deviation over the ERS period (exploitation phase)
- Small standard deviation after

ERS Time Series – Exploitation period

- Initial displacement: 1997/09/03
- Blue: 29 (a.); Black: 65 (d.); Red: Tr. 294 (d.); Green: levelling



Bollwiller – 143



Pulversheim

Full Time Series

- Traditional law (Knothe, 1957)

$$S(t) = S_0 \times (1 - e^{-ct})$$

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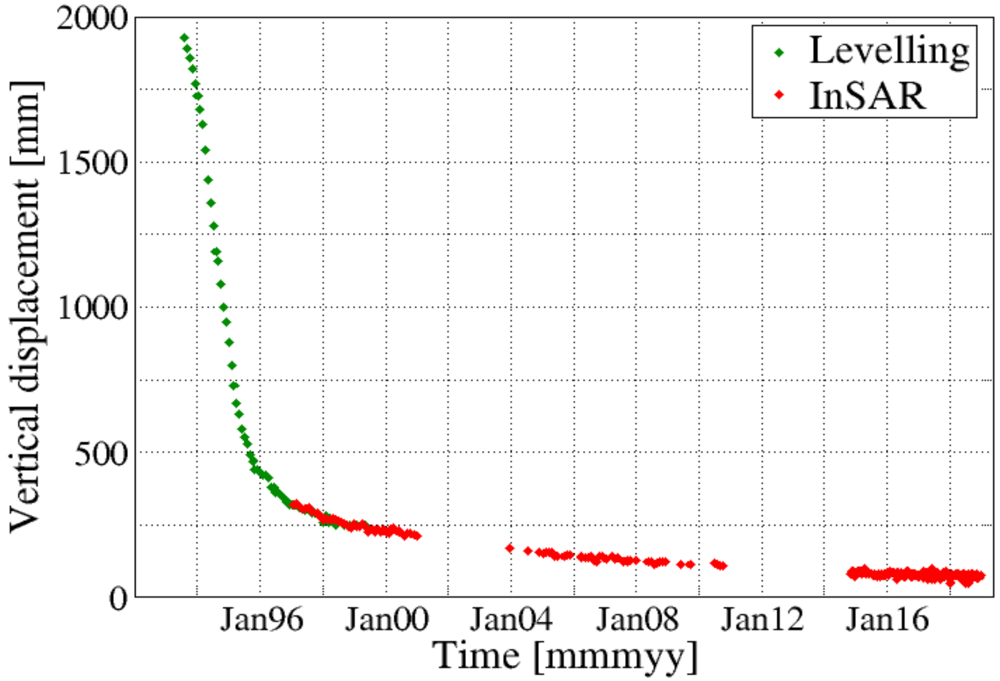

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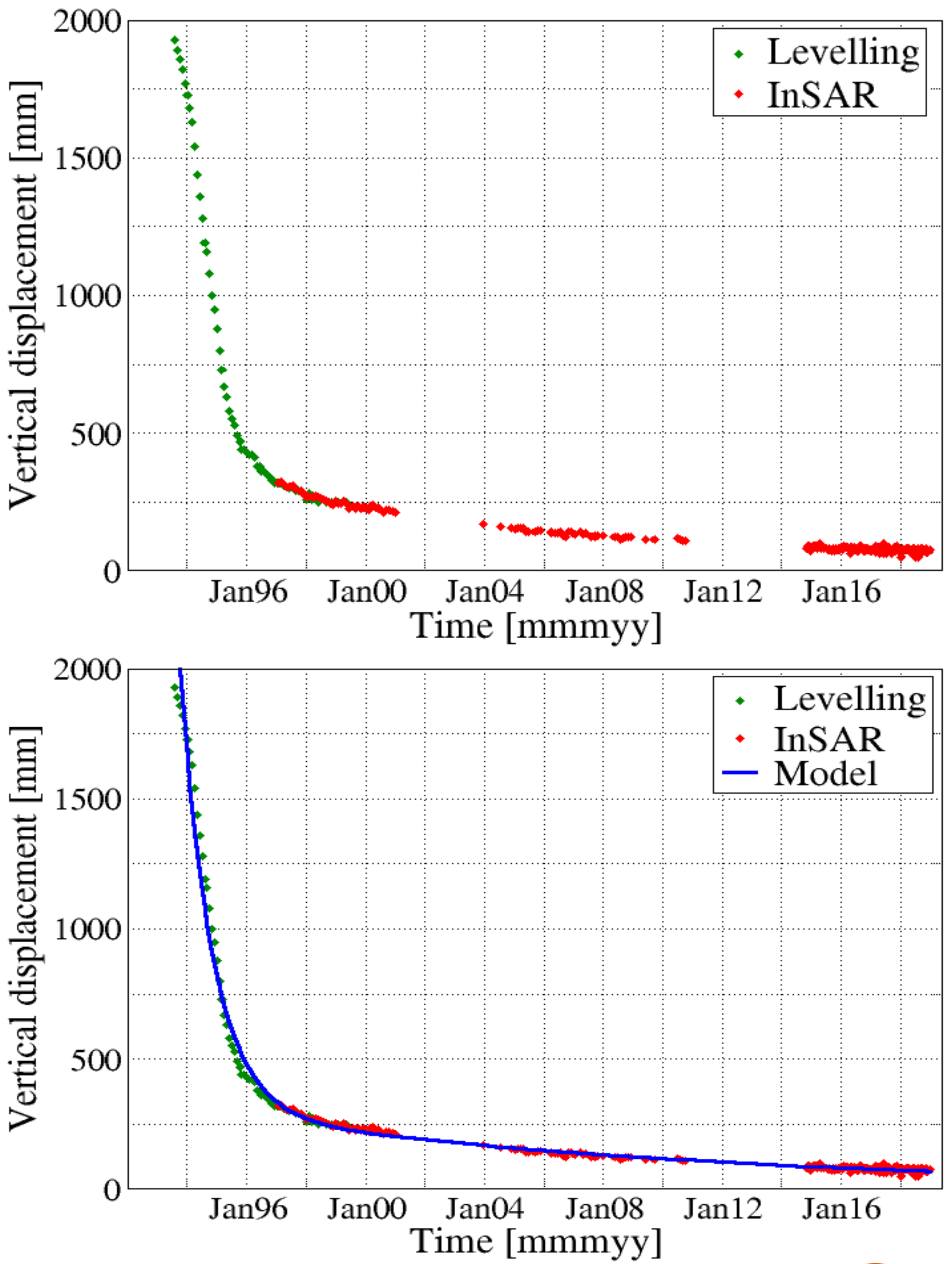

Time factors

- ξ_1 insignificant after 10 years and related to the overburden response
- Good agreement between c and ξ_1
- ξ_2 insignificant after 100 years and related to the void closure (goaf compaction, fractures closure)

Levelling point	c [y^{-1}]	ξ_1 [y^{-1}]	ξ_2 [y^{-1}]
Bollwiller – 143	0,78 – 0,91	0,92 ± 0,02	0,048 ± 0,002
Bollwiller – 193	0,78 – 0,91	0,90 ± 0,03	0,058 ± 0,003
Bollwiller – 210	0,78 – 0,91	0,72 ± 0,02	0,049 ± 0,002
Pulversheim	0,84 – 0,98	0,93 ± 0,01	0,06 ± 0,001
Raedersheim	1,48 – 1,73	1,32 ± 0,03	0,041 ± 0,001

Residual Subsidence

- Estimation of the beginning of the residual phase from an exploitation map
- Cumulative displacements over only the three monitored periods
- First publication: relation with the extracted height (Orchard and Allen, 1974)
- Recent publications: relation with the total subsidence (Al Heib et al., 2005)

Levelling point	Start of the residual subsidence	Active subsidence (levelling) [cm]	Residual subsidence (INSAR) [cm]	Residual subsidence / Total subsidence [%]	Residual subsidence / Extracted height [%]
Bollwiller – 143	1997	273	14	4,9	3,6
Bollwiller – 193	1996	278	16	5,4	4,2
Bollwiller – 210	1996	141	14	9,0	3,6
Pulversheim	1997	234	18	7,1	4,5
Raedersheim	1997	54	11	16,9	3,6

Conclusion

❌ Mining phase

✅ Residual phase

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\- Monitoring of salt galleries closure with lidar

Thank you !