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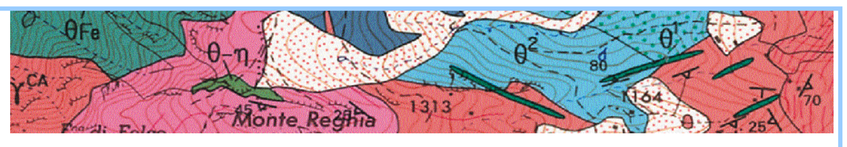

Combined use of Sentinel-1 and SMOS data with the BSS subsurface database to better estimate the shrink-swell hazard in Southwestern France

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Two main questions:

(1) Are the local displacements detected by Sentinel-1 strongly related to the underground gas storage operations?

(2) Can the DInSAR processing and SMOS data be coupled to assess locally the shrink/swell hazard in Southwestern France?

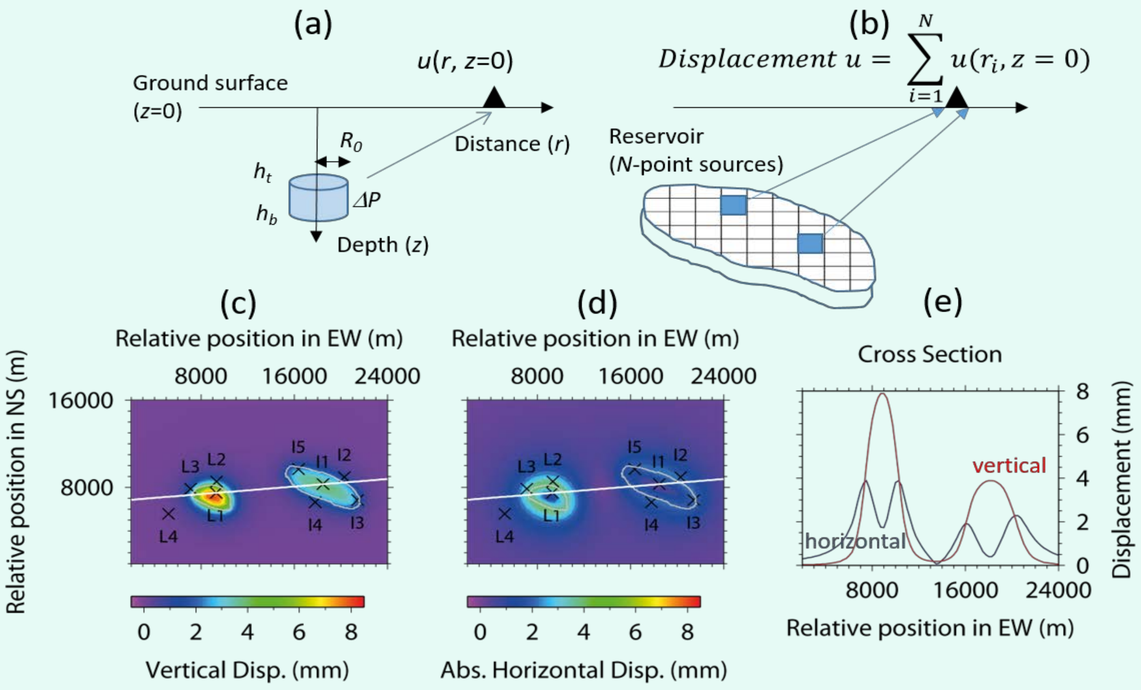
Sentinel-1 data and mechanical modeling

Table S1: Sentinel-1 and SqueeSAR® parameters

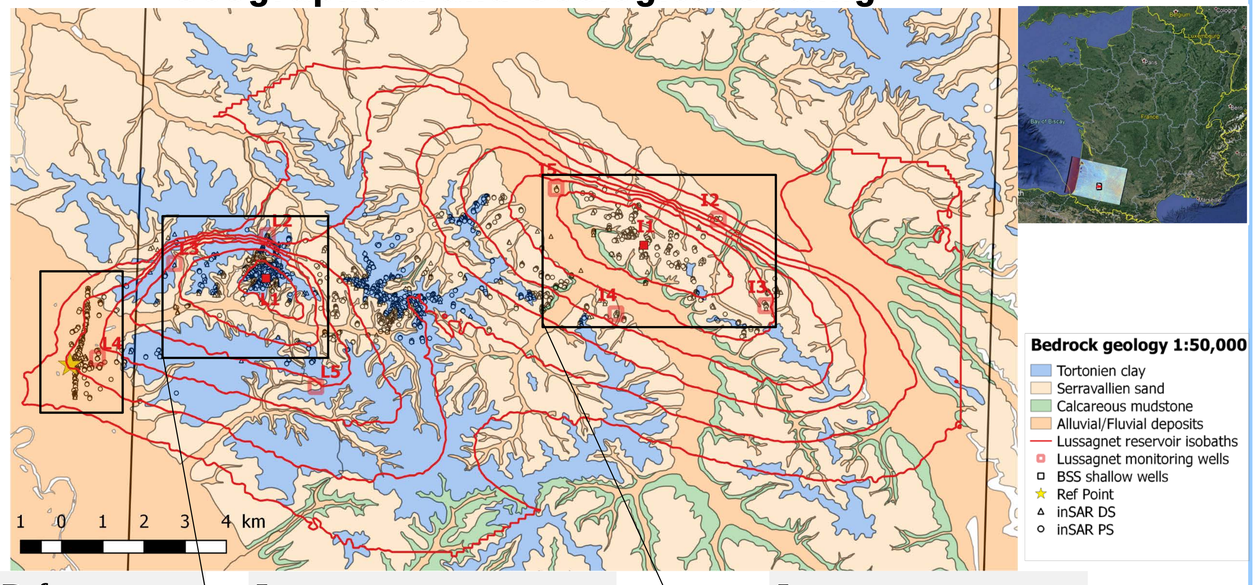
Track number	8
Geometry	Descending
# of images	115
Time period	18/10/2014-26/10/2017
Look angle θ (°)	37.97°
Azimuth angle δ (°)	8.19°
Number of measurement points (MP)	1931
Area	87.5 km²
Measurement point density	22.1 MP/ km²
Coordinate reference system	NTF (Paris) Lambert Zone III
Reference point	X coordinate: 389548.84 Y coordinate: 3165408.00

Table S2: Mechanical model parameters

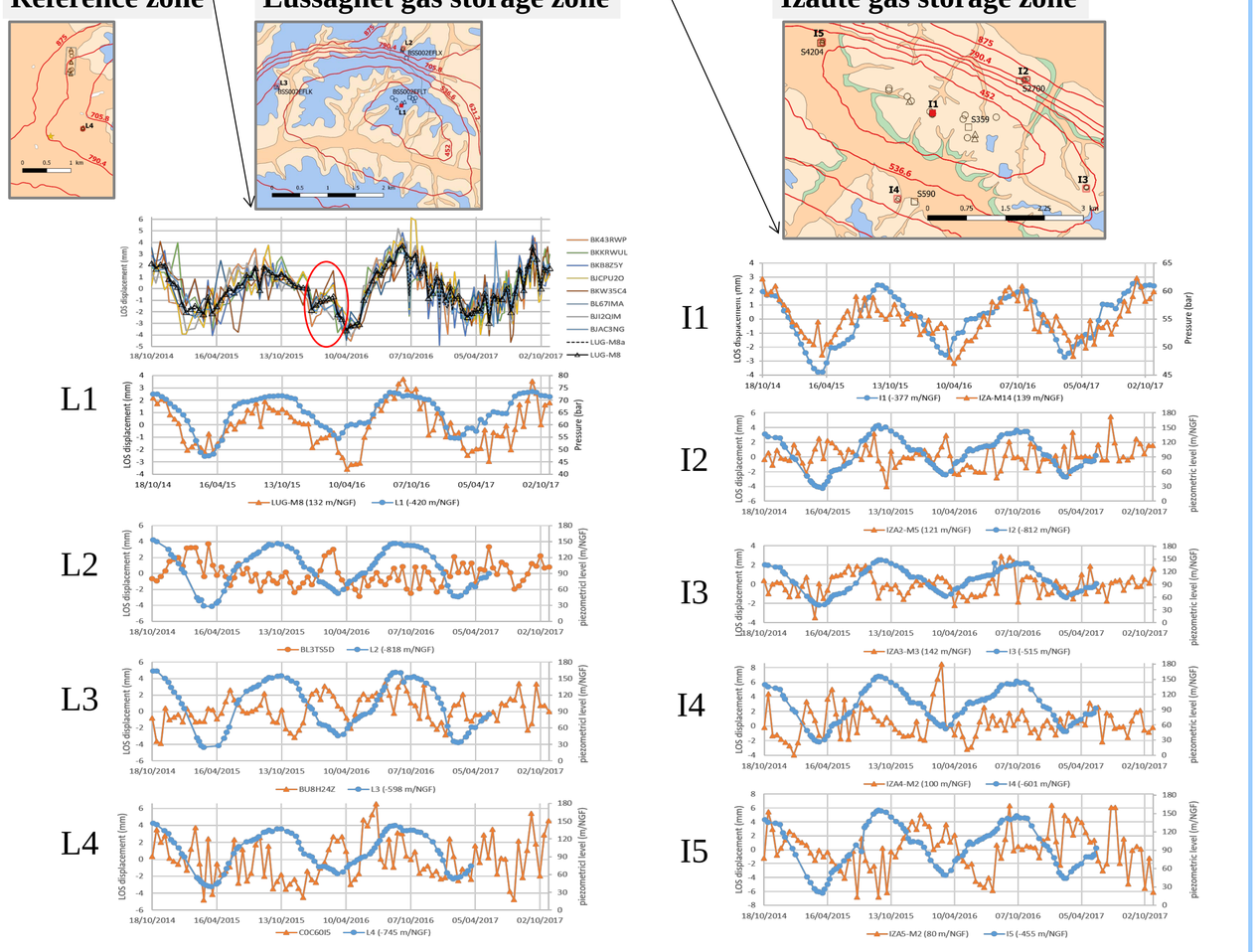
Parameter	Quantity and Unit
Poisson ratio ν	0.3
Medium rigidity μ	8 GPa
Biot's coefficient α	0.9
Lussagnet reservoir (surface S, top depth h_t, bottom depth h_b)	(5.4 km², 550 m, 715 m)
Pressure change ΔP in Lussagnet reservoir	20 bar
Izaute reservoir (surface S, top depth h_t, bottom depth h_b)	(13.1 km², 510 m, 590 m)
Pressure change ΔP in Izaute reservoir	15 bar



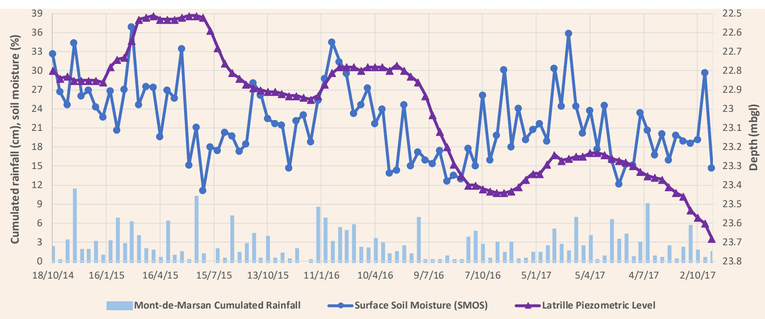
Geographical and Geological Setting

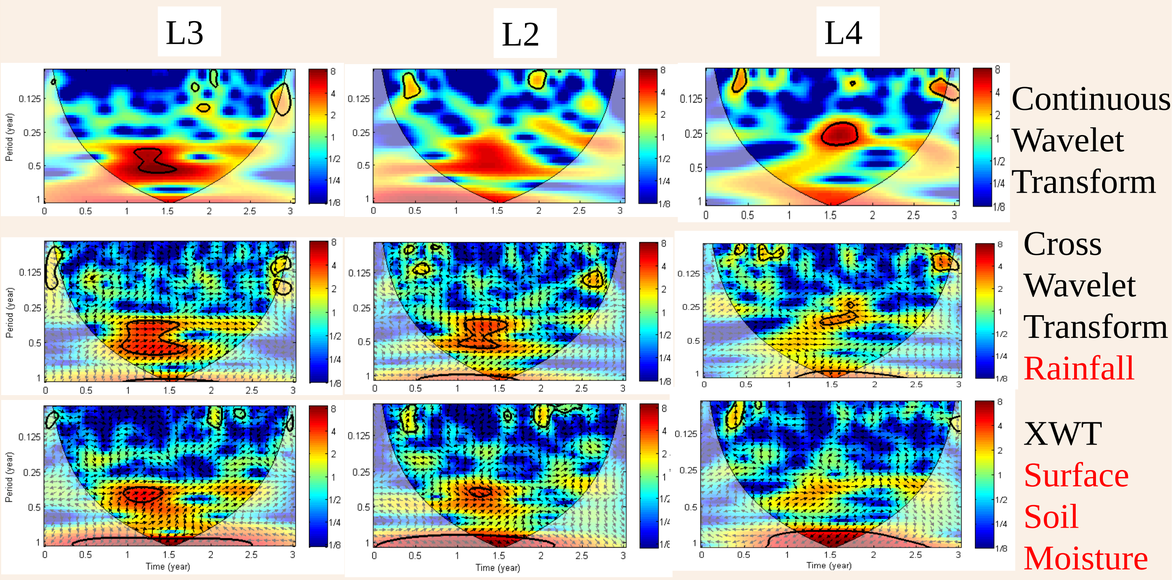


Reference zone | **Lussagnet gas storage zone** | **Izaute gas storage zone**



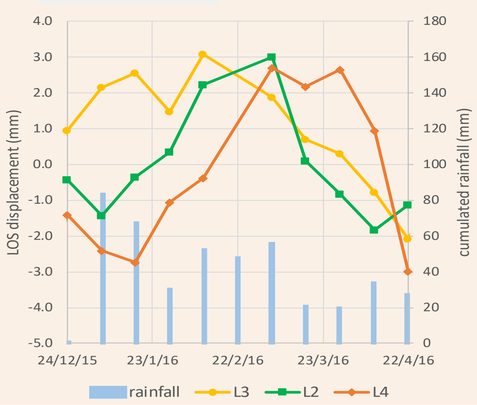
Wavelet-based analysis of LOS displacement using hydraulic data



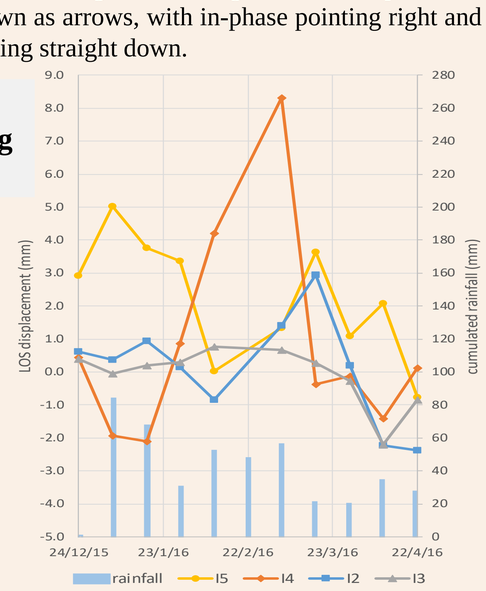


In the top, the continuous wavelet transform (CWT) of the mean LOS displacements is shown at 3 monitoring wells of Lussagnet: (a) L3, (b) L2, (c) L4. In the middle, the cross wavelet transform (XWT) of the cumulated rainfall and the LOS displacement at trree monitoring wells is shown. The thick contour designates the 5 % significant level against red noise. The cone of influence (COI) where edge effects might distort the picture is shown as a lighter shadow. The relative phase relationship is shown as arrows, with in-phase pointing right and anti-phase pointing left and the rainfall/SSM leading by 90° pointing straight down.

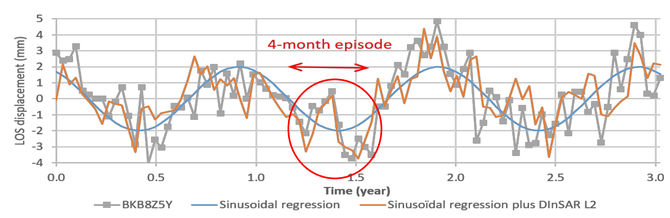
Lussagnet monitoring wells



Izaute monitoring wells

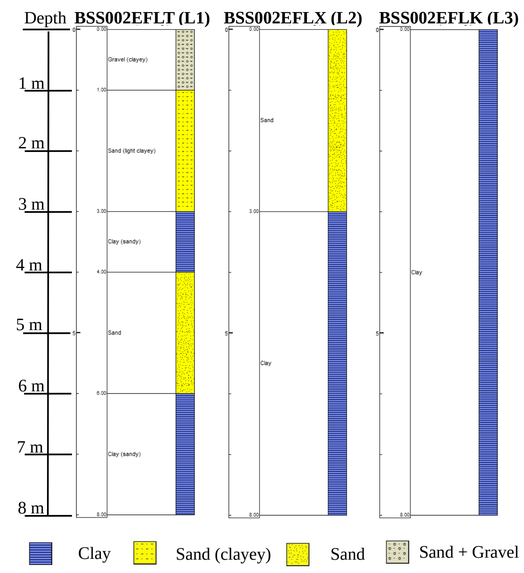


Modeling of LOS displacement at Lussagnet site during the 4-month episode



$$SR(t) = A_{max}\cos\big((t+\varphi)\times 2\pi/T\big) \qquad (1)$$

$$M(t) = SR(t) + L2(t) \qquad (2)$$



Geological Logs extracted from the BSS subsurface database (http://infoterre.brgm.fr/)

Conclusions

I. **A vertical ground deformation between 4 and 8 mm is detected by DInSAR during the summer and winter periods due to the gas exploitation at both gas storages sites (Lussagnet and Izaute).**

II. **The wavelet-based analysis reveals a soil expansion in the Lussagnet zone that contrasts both in phase and period with the seasonal deformation and that is linked to the surface soil moisture measured by the SMOS satellite. This other displacement is consistent with the water infiltration in the unsaturated zone followed by the swelling of a clay layer (as given by BSS subsurface database).**

III. **This work reveals the combination of two different processes driving the ground displacement with the same order of magnitude (about 6 mm), namely the pressure variation of a deep gas reservoir and the swelling/shrinking of the shallow subsurface.**

Acknowledgments

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