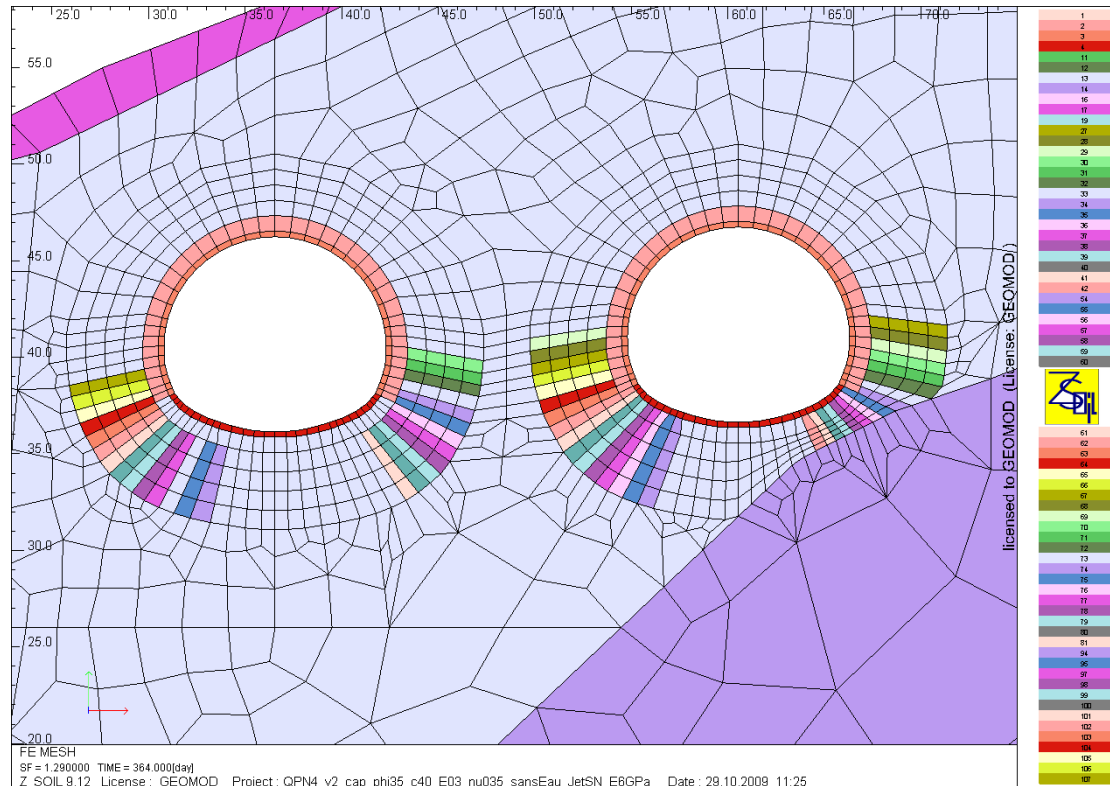
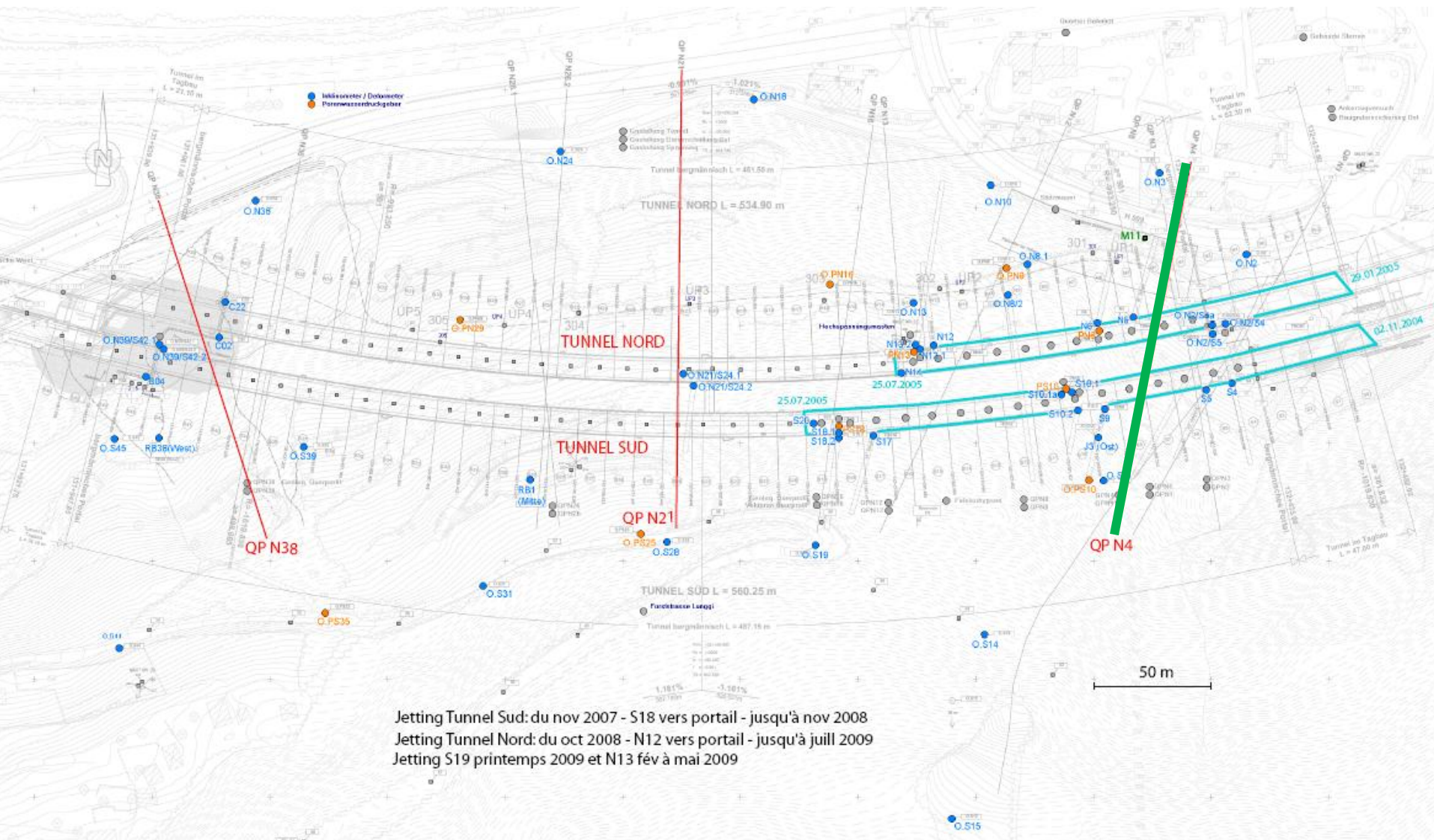


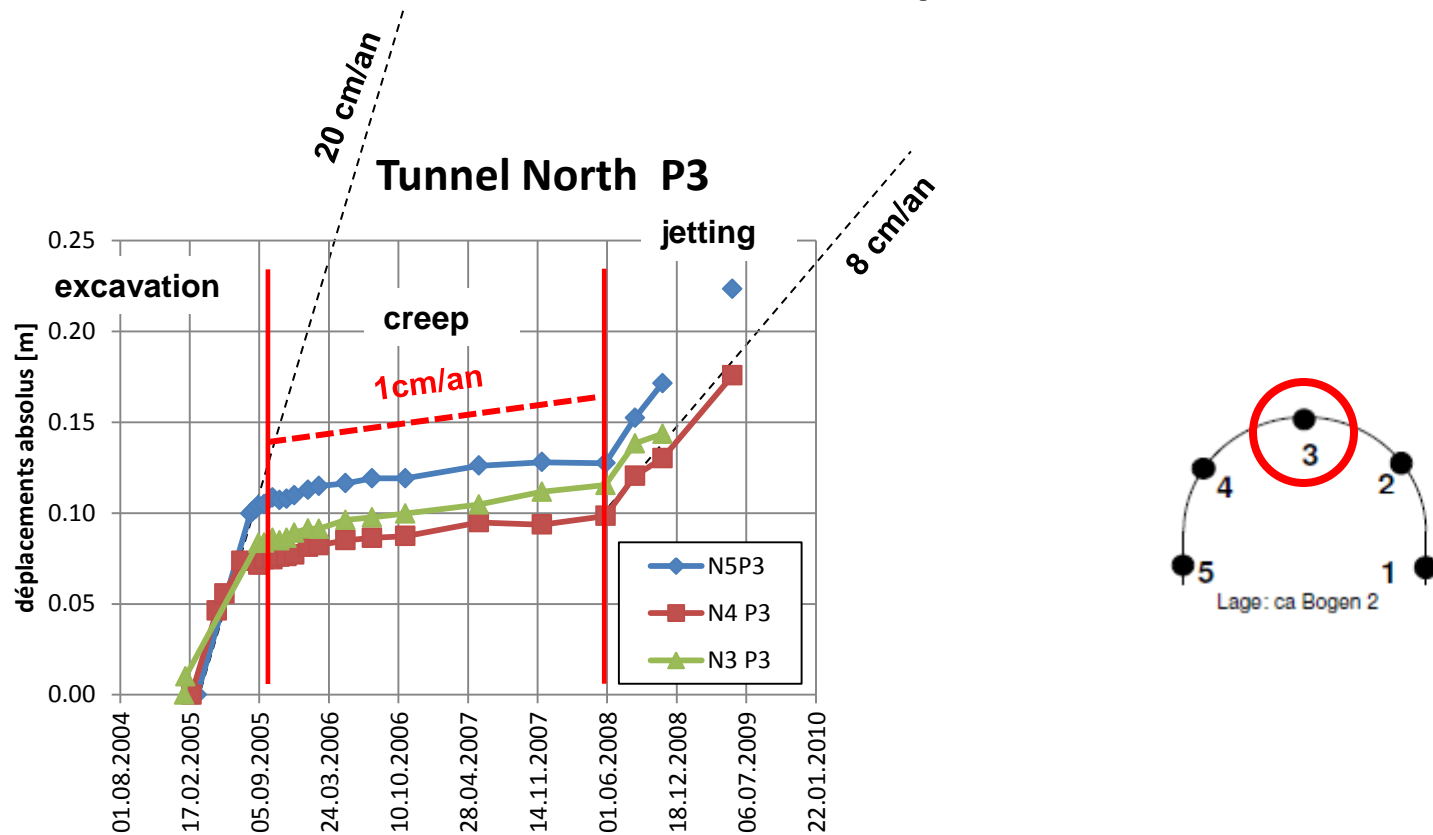
Two-dimensional FE analysis on the influence of jet grouting on displacements around a tunnel



Stéphane Commend, Rafal Obrzud, Françoise Geiser
GeoMod SA - Lausanne



QPN4: IN SITU MEASUREMENTS (TUNNEL CROWN)

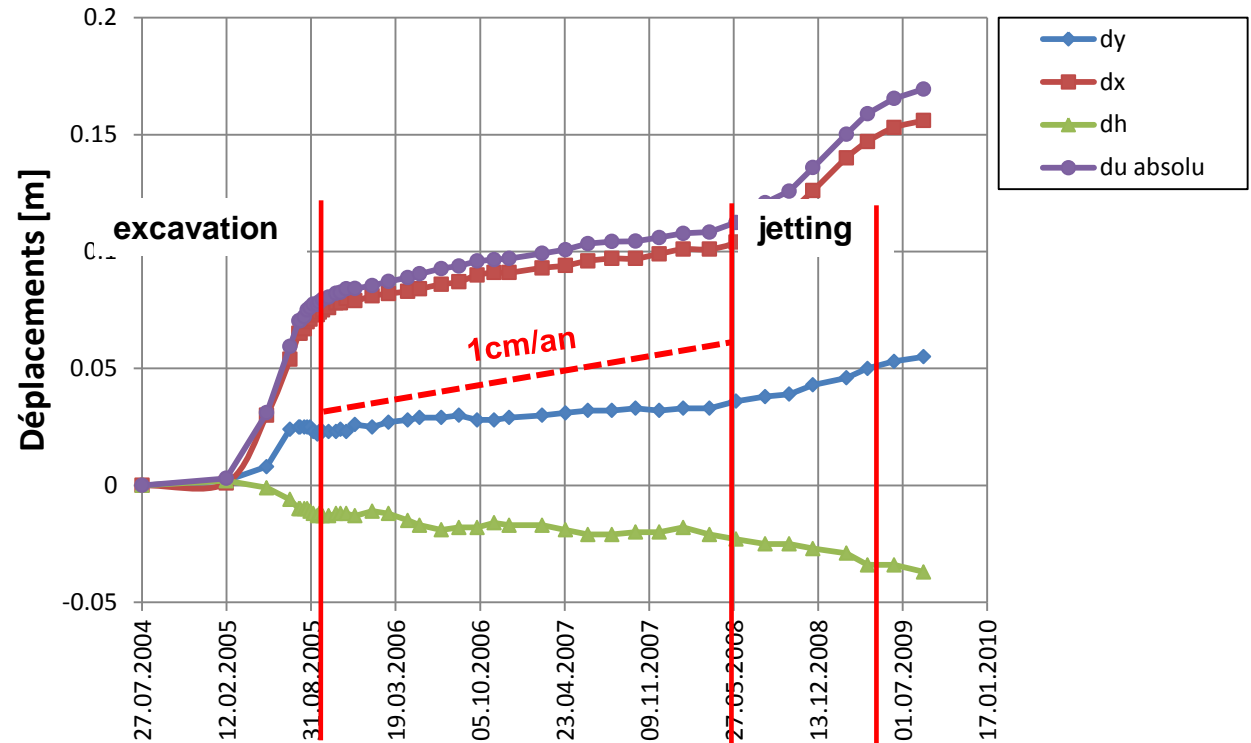
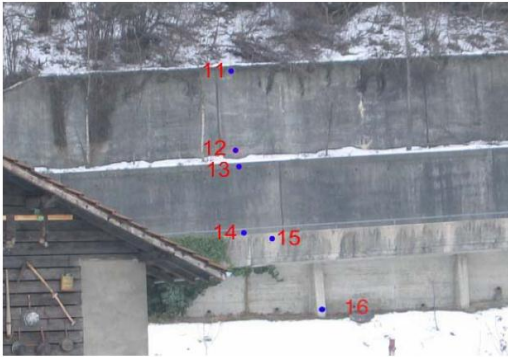


- Jetting induces significant displacements !

QPN4: IN SITU MEASUREMENTS (RETAINING WALL)

QPN4: Point des mesures M11

Messquerschnitt QP4

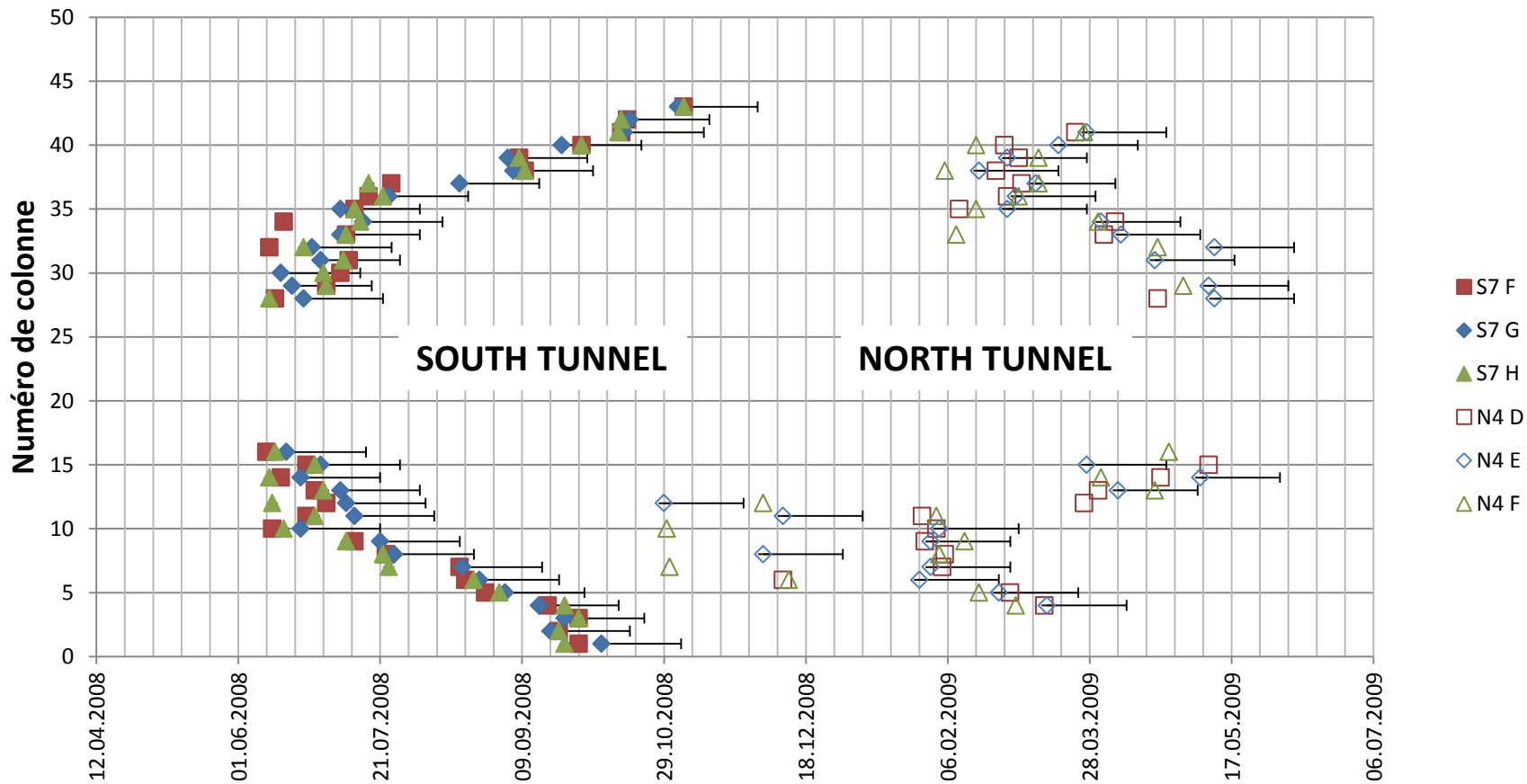


- Same behavior: jetting induces displacements!

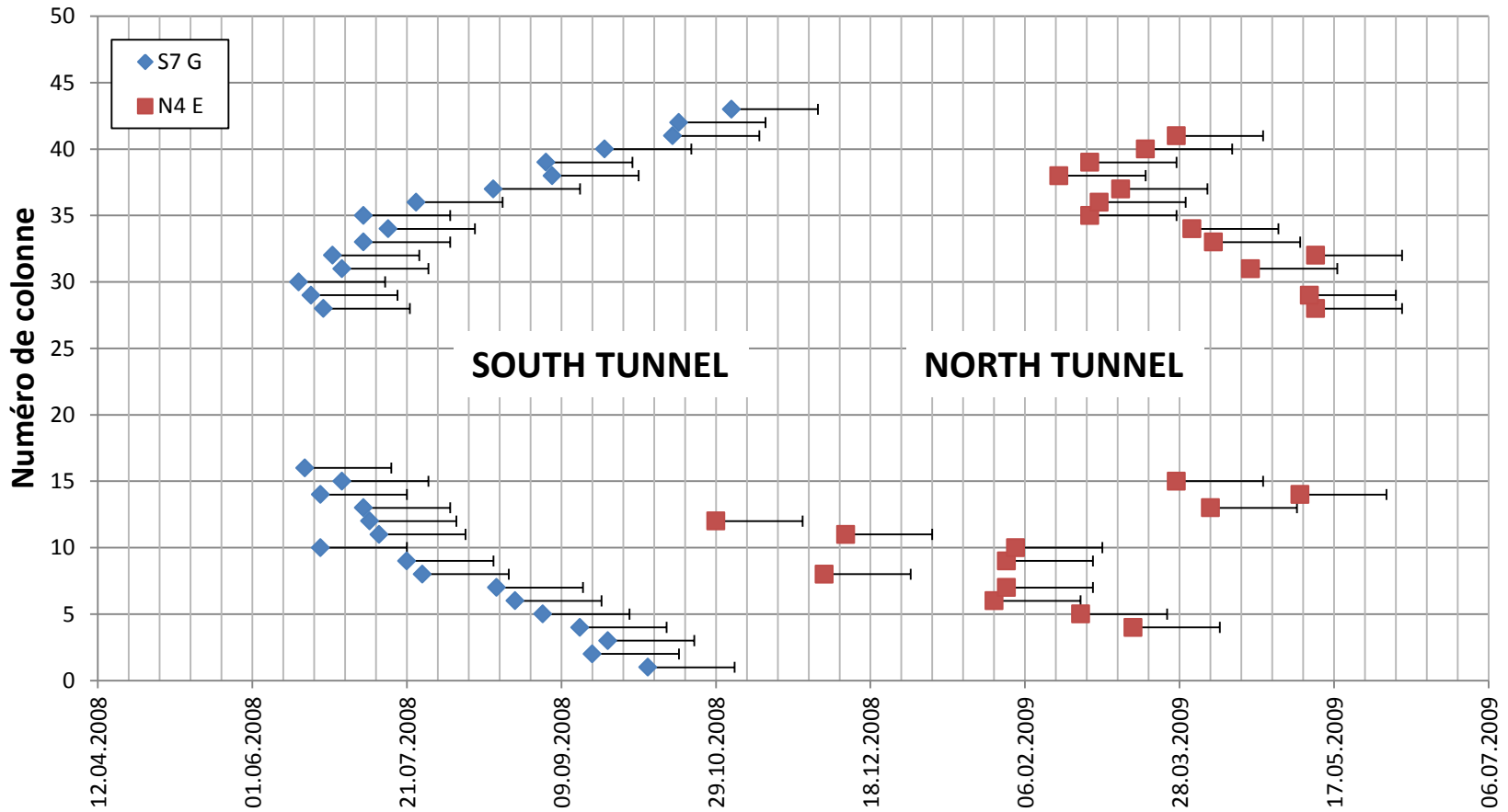
Main difficulty

- «classical» taking into account of jetting (instantaneous material replacement with column strength \gg soil strength) won't yield displacements !

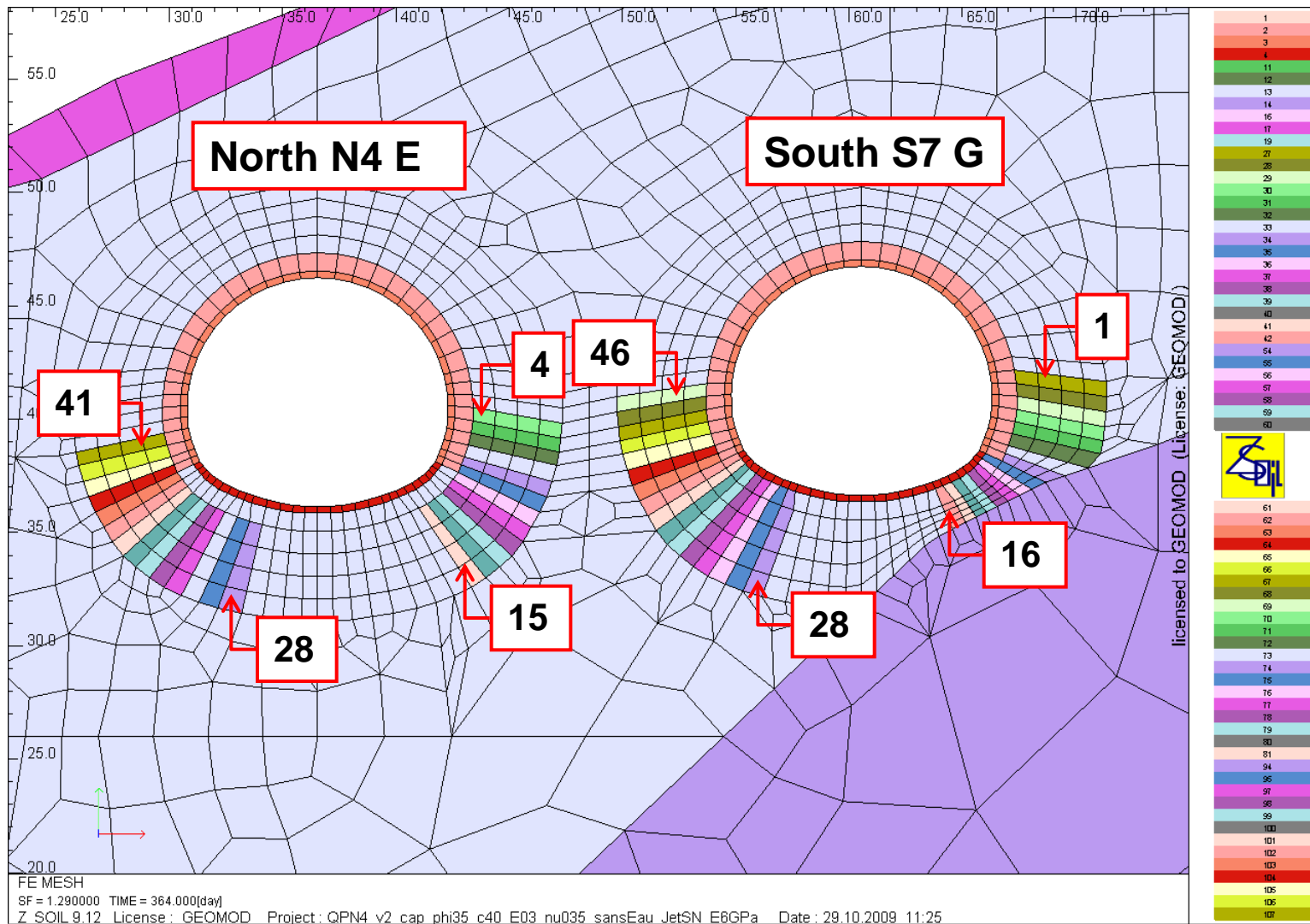
JETTING SCHEDULE (REAL)



JETTING SCHEDULE (MODEL)



QPN4: JETTING COLUMNS IN FE MODEL



QPN4: JET COLUMNS MODELING

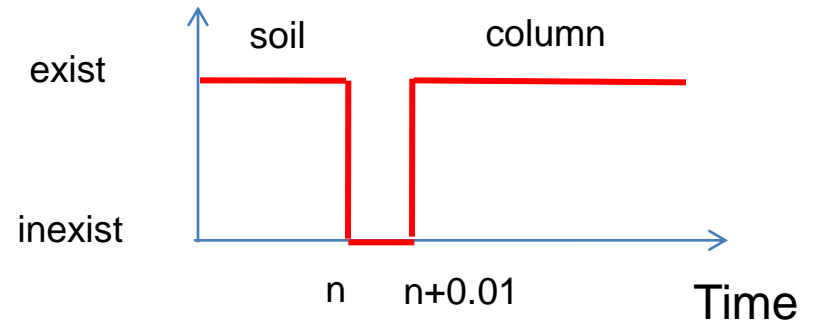
General hypotheses

- Taking into account of:
 - unloading due to initial fluid-like behavior of jetting material in every column
 - progressive cementation through time
 - time and spatial sequence of columns construction
- Elasto-plastic constitutive modeling:
 - Soil: Cap-model
 - Jet columns: Drucker-Prager
- Total stress computation => water and overpressure during jetting are NOT taken into account

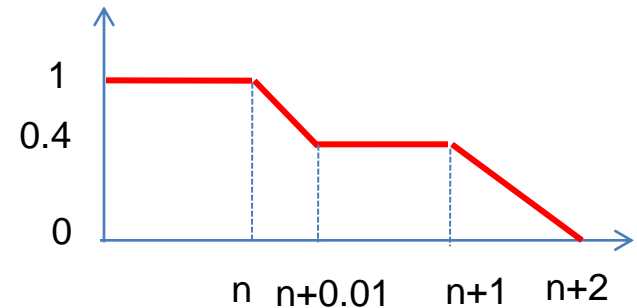
Jetting modeling

Each column is defined by:

-Existence function

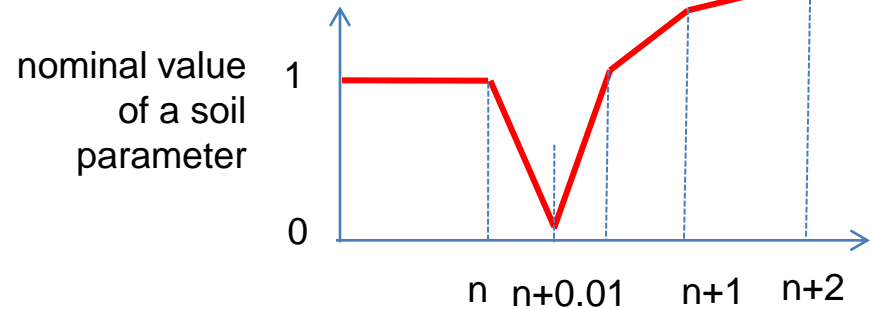


-Unloading function
(3D effect)



-Replacement material
(soil -> jet)

- Parameter evolution
(liquid soil -> final column)



Jetting modeling

Initial parameters:

Soil (Cap)		
c	40	kPa
ϕ	35	deg
f_c	360	kPa
f_t	18	kPa

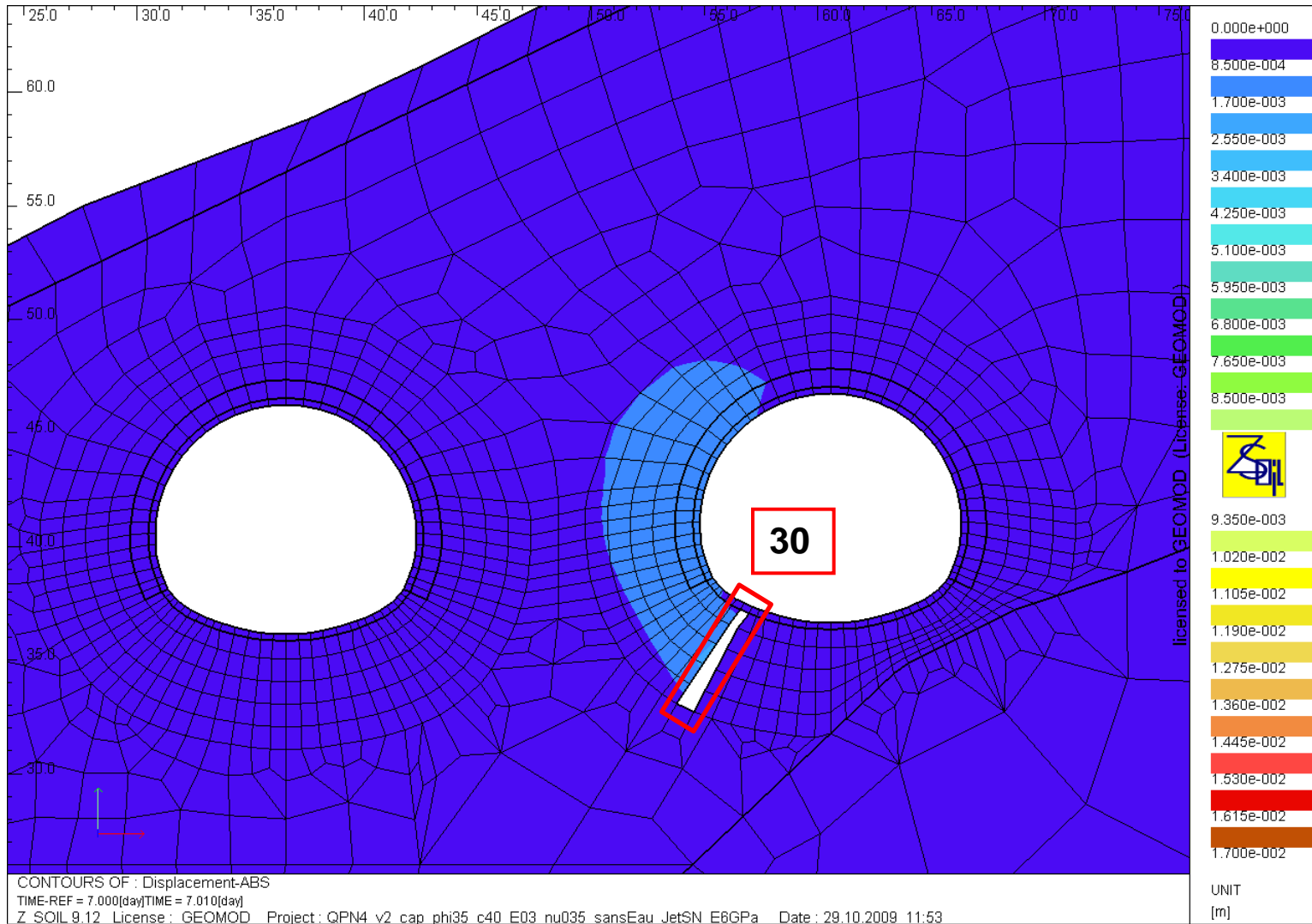
Jetting column
(final state):

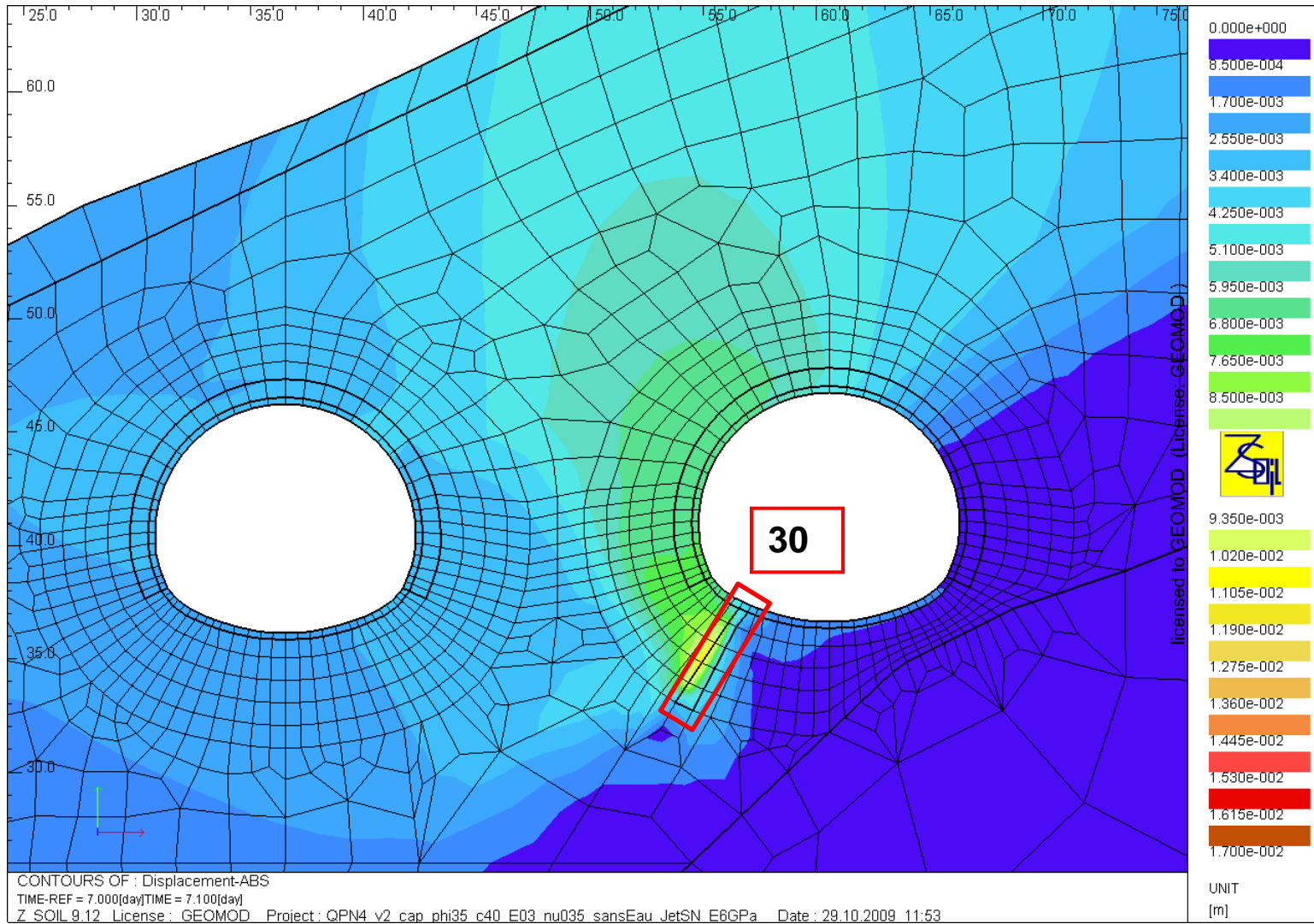
Column (final state) (D-P)		
f_c	5'000	kPa
f_t	500	kPa
c	790	kPa
ϕ	55	deg
E	6'000	MPa

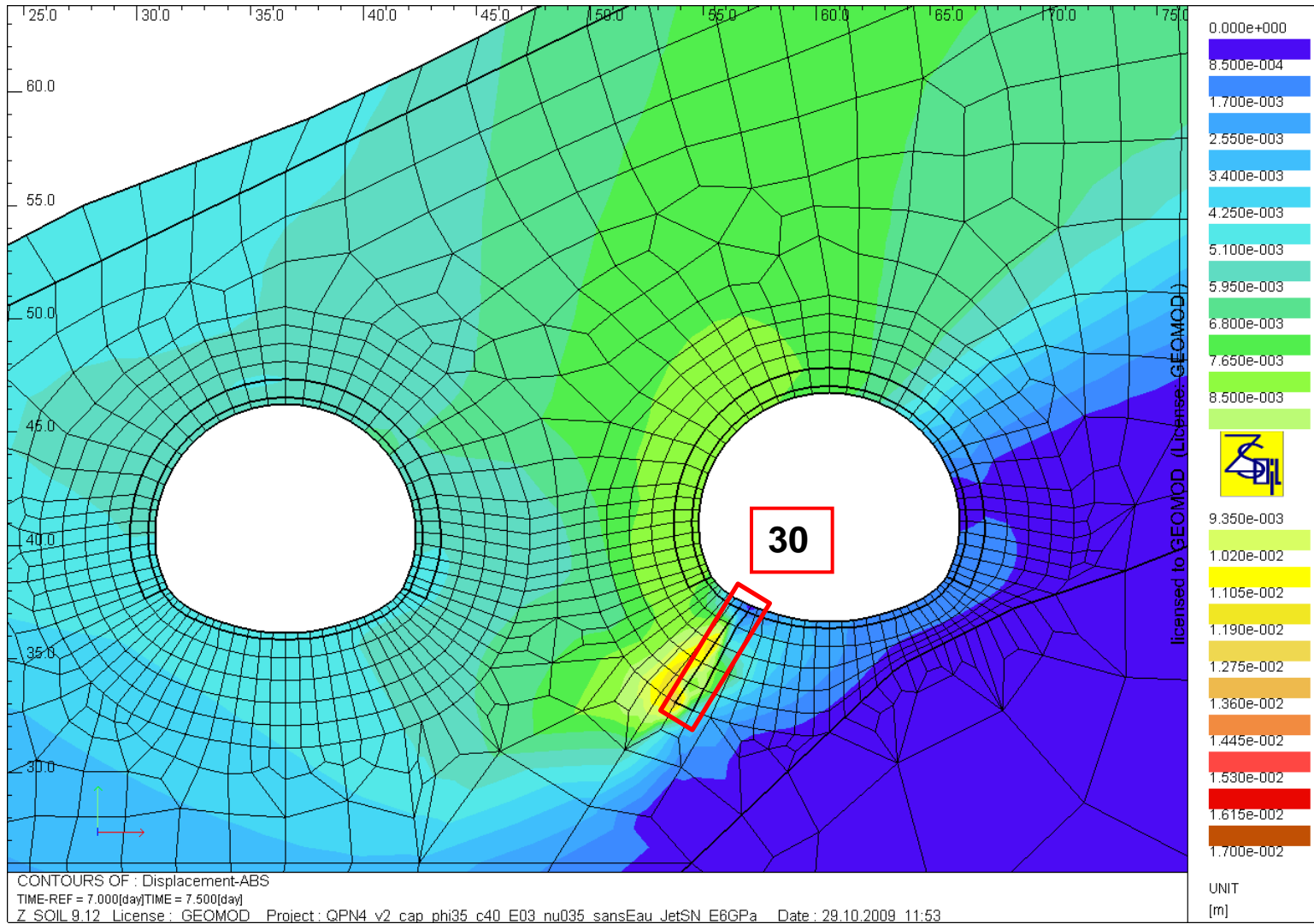
$$c = 0.5\sqrt{R_c R_t}$$

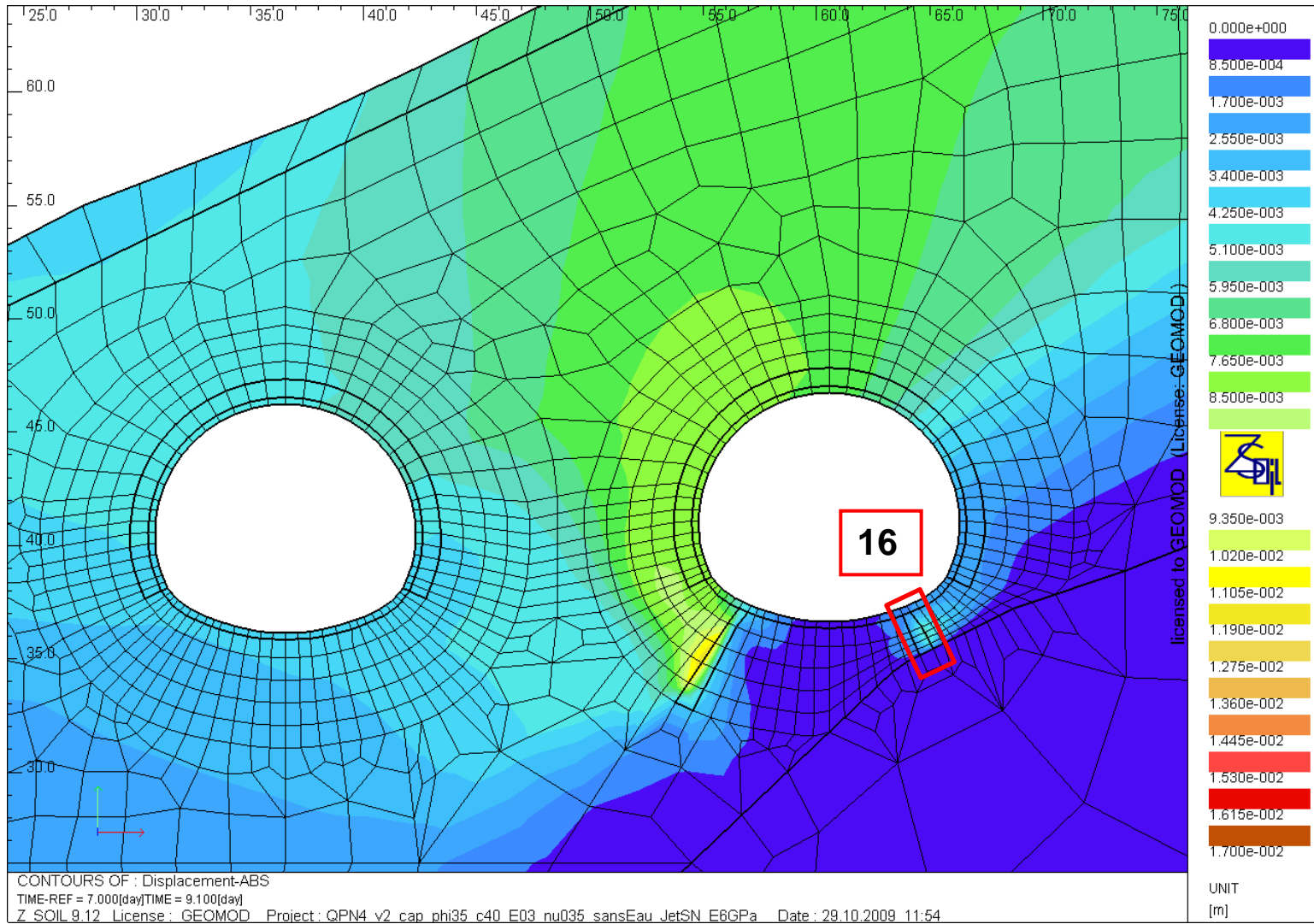
$$\phi = \arcsin\left(\frac{R_c - R_t}{R_c + R_t}\right)$$

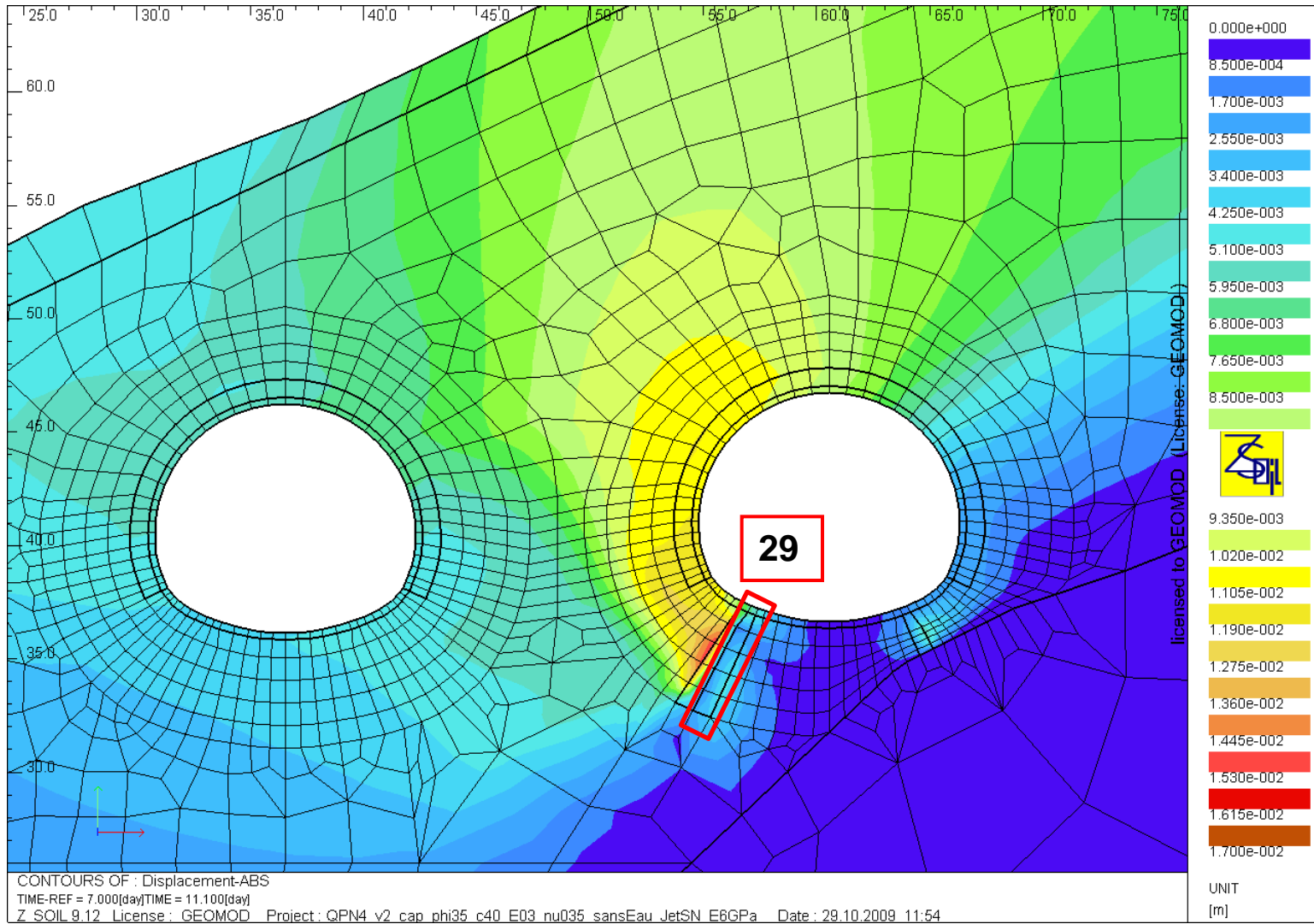
Displacement evolution around tunnels during jetting

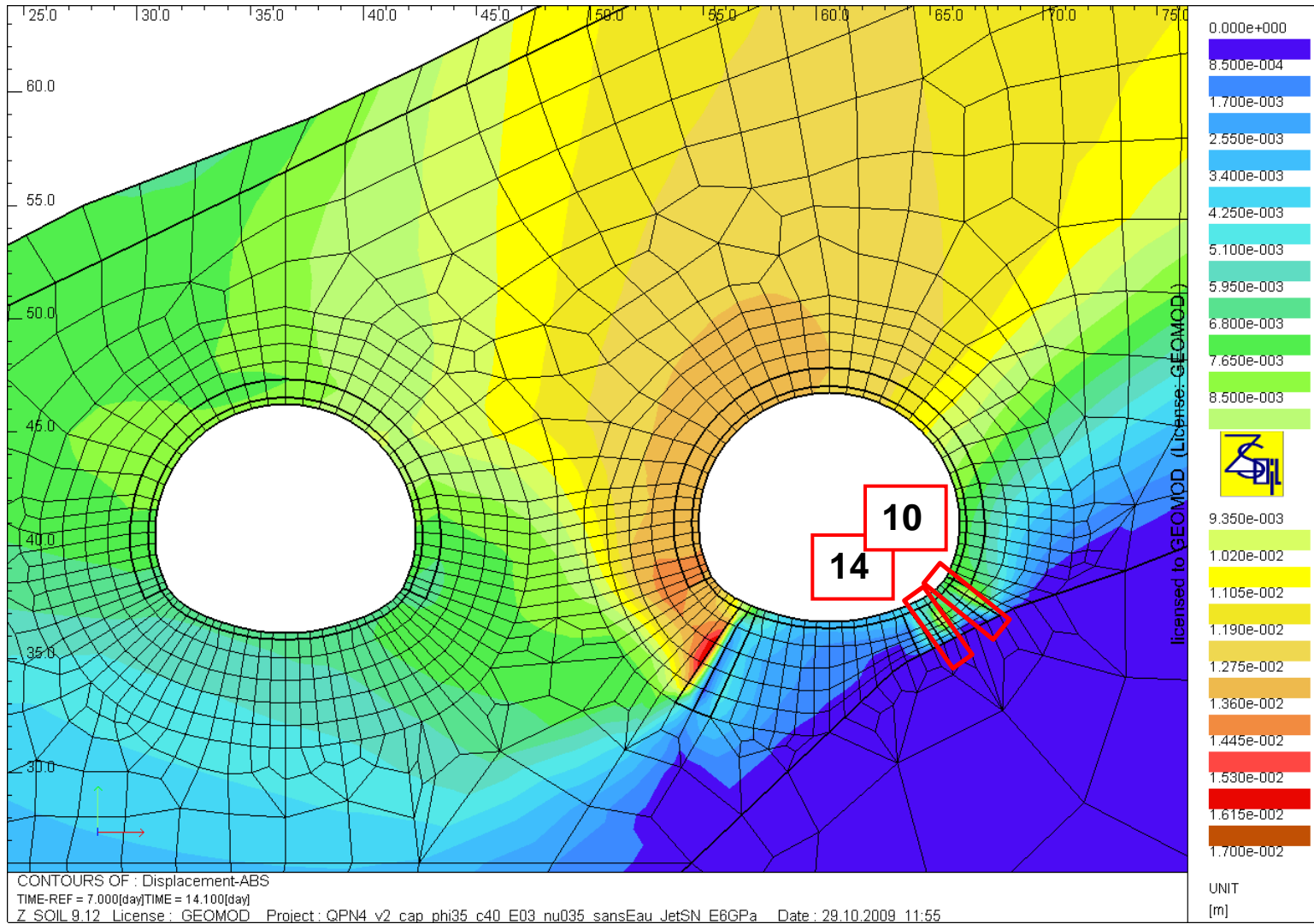


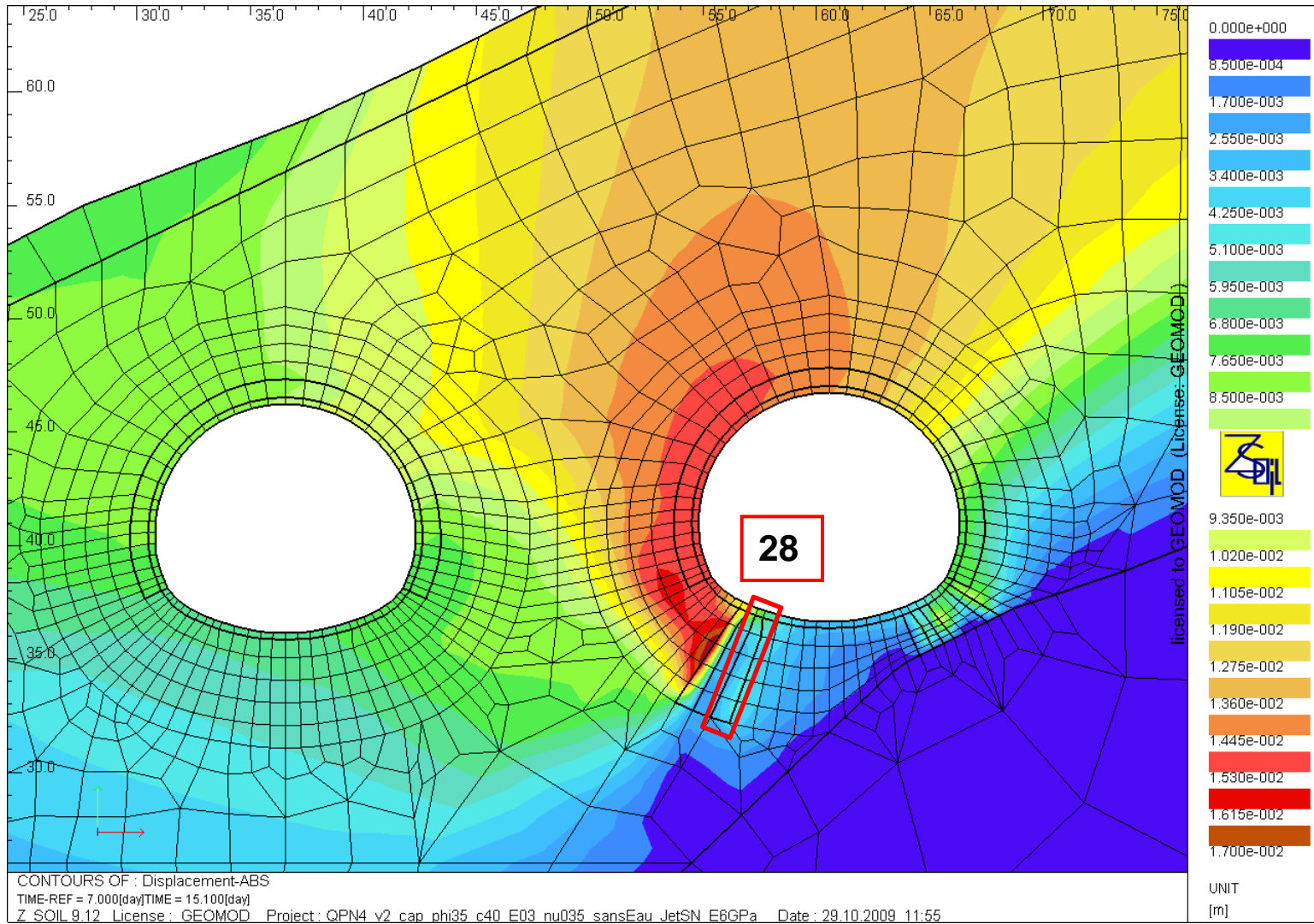




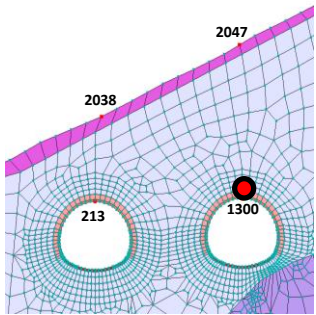




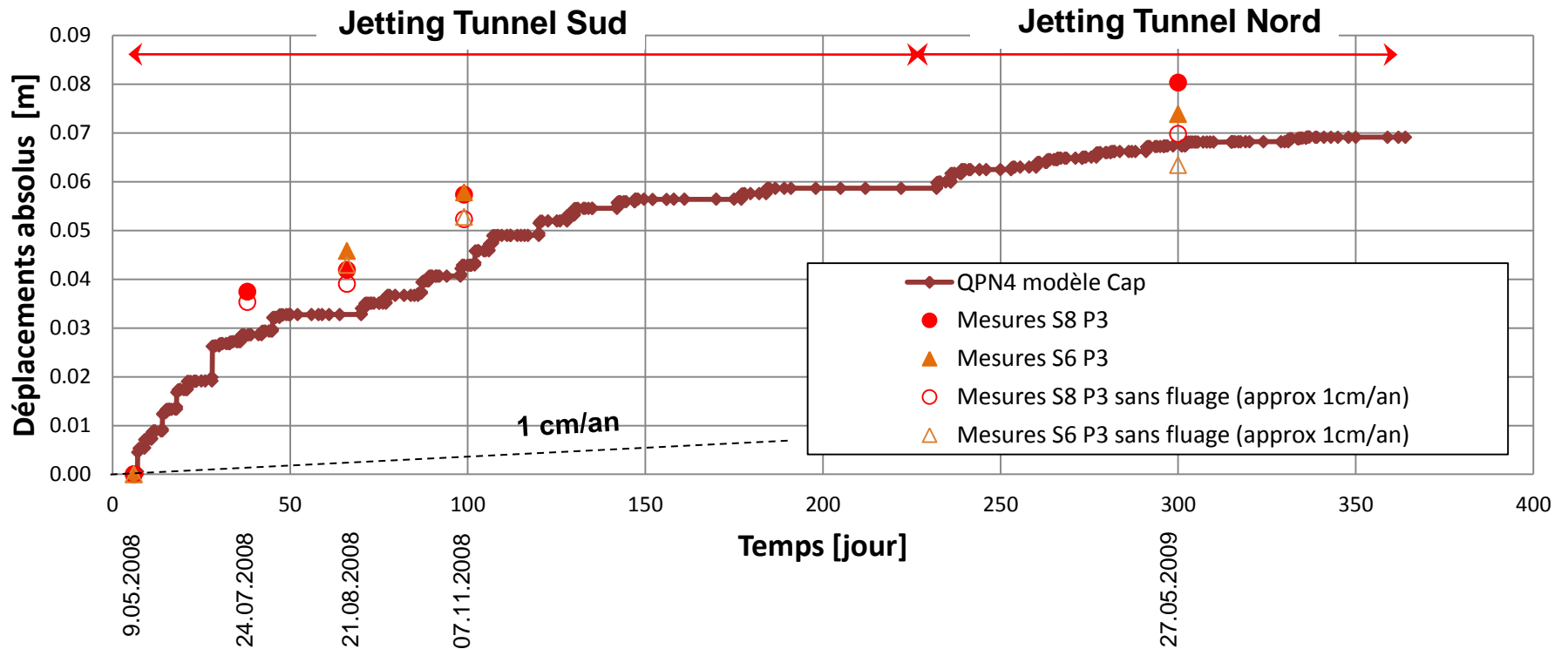




QPN4: Comparison in situ measures – model

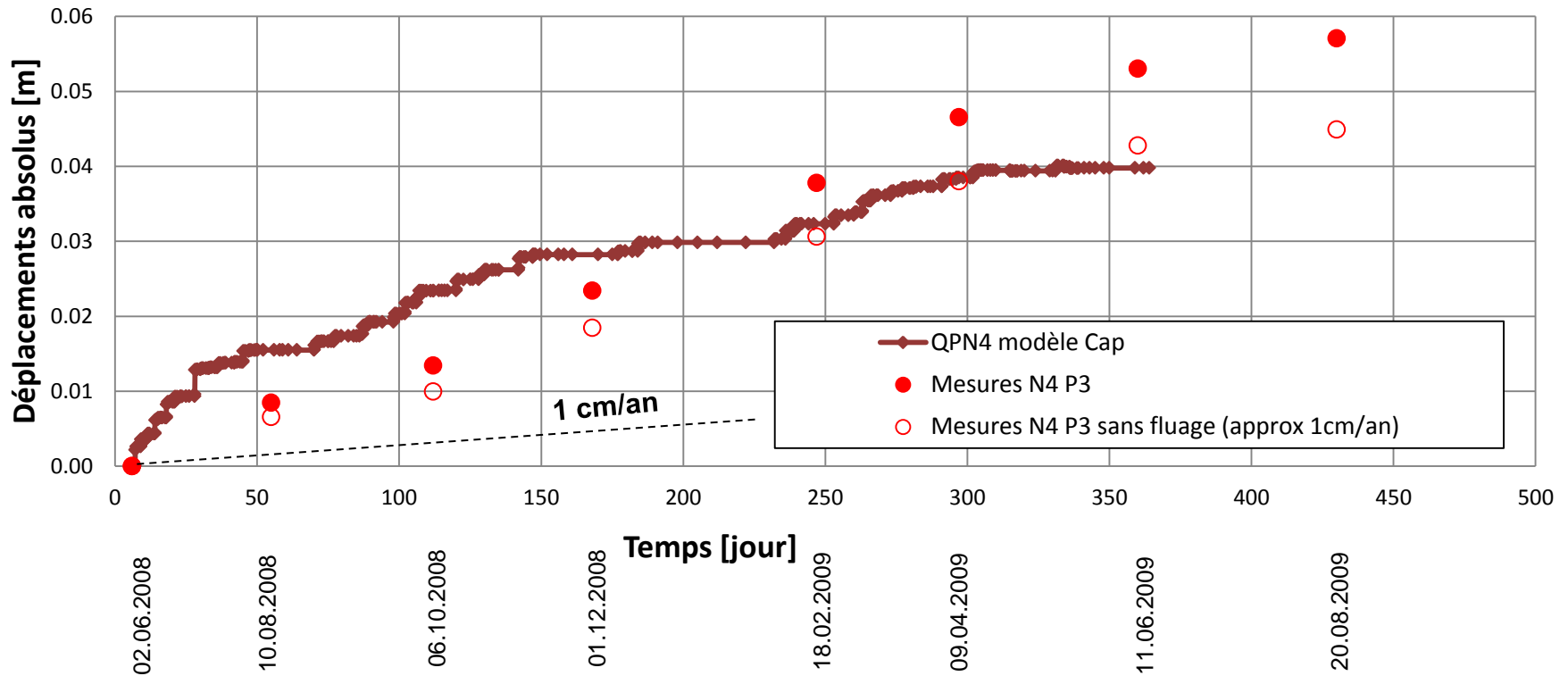


Abs displacements Pt 1300 vs. **P3 Tunnel Sud** (jetting only)



QPN4: Comparison in situ measures – model

Wall: Abs displacements Points 897 vs M11 (jetting only)



- Le mouvement du mur aval est également correctement modélisé
- En conclusion, le modèle numérique peut être considéré comme un outil prédictif assez fiable

Conclusions

- In situ measurements have shown displacements due to jetting around the tunnels only (no excavation)
- «classical» taking into account of jetting (instantaneous material replacement with column strength \gg soil strength) won't be able to represent that
- «advanced» method with evolution of parameters yields comparable results with in situ measurements