Cross cutting theme: Soil quality

Soil texture analysis by laser diffraction – method and instrument comparison with a focus on Nordic and Baltic forest soils

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Our mission

Comparison of particle size distributions from three laboratories applying their own operating procedures and laser diffraction instruments on a set of soil samples from boreal and temperate forest soils

Challenge: Igneous rock, mafic and felsic minerals in parent materials, biogenic and sedimentary rocks – Moh's scale

- Soils formed in: MAT -2 to 8 ºC and MAP 300 – 4000 mm yr^{-1} on highly diverse parent materials

Iron rich Podzol, Jølster, Norway (O. Janne Kjønaas), weak soil development in Arenosol, Kalsnava forest, Latvia (Ingeborg Callesen), volcanic Brown Andosol with black basaltic ash layers which can be used to date the profile. At 60-70 cm is Hekla 1510, Árnes, Iceland, (Ólafur Arnalds). Classification according to World Reference Base (2015).

Many available methods and instruments for soil texture analysis - combinations

Basics for physics: Laboratory with constant temperature, free of vibrations

- Sieving, many sieve systems: for ISSS a 2 mm, and a 200 µm are essential
- Hydrometer – needs a calibrated floating weight and mm paper – some are very old – very tedious calibration (Day, 1950)
- Pipette – quite rare

- Laser diffraction – debated – many brands and models - widely used on soil samples range ~0 – 2 mm
- Pario and Pario+, based on the ISP method (Dürner, 2017, 2020)

References:

Rasmussen, C, 2020. Particle Sizing in Geosciences: Explanation of Various Techniques and Pre-treatments. Aarhus University, Denmark. E-book url: https://ebooks.au.dk/aul/catalog/book/374, doi.org/10.7146/aul.374

CARES III: Three laser diffraction instruments

- Coulter LS230, Helsinki University

- Malvern Mastersizer 2000, range 0.02 my to 2 mm, wet and dry unit

Mastersizer 2000 technical specifications

Optical Unit	Specification
Size range	Materials in the range 0.02µm to 2000µm
Measurement principle	Mie scattering
Detection systems	Red light: forward scattering, side scattering, back scattering Blue light: wide angle forward and back scattering
Light sources	Red light: helium-neon laser Blue light: solid-state light source
Optical alignment system	Automatic rapid align system with dark field optical reticle
Sample dispersion unit interchange	Sample dispersion units automatically recognized, configured and enabled on insertion of measurement cell cassettes into sizer
Laser system	Mastersizer 2000: Class 1 laser product Autosampler 2000: Class 2 laser product

- Sympatec Helos, range 0.0018 mm – 3.5mm, three lenses
  - Wet unit
  - Gravimetric dry unit

Laser diffraction is not a wonder method, pretreatment of samples is still needed

Basic treatment is air-drying, gentle crushing and 2 mm sieving

Evaluate:

- Humus (Carbon) 0 – 20% (10%)
- Calcium carbonate (0 – 50%)
- Sesquioxides (0 – 10%)

Pretreatment to disperse particles, break aggregates:

- Ultrasonication
- Mechanical mixing by milkshaker
- End-over-end shaking
- Chemical dispersing agent: $Na_4P_2O_7 \cdot 10H_2O$

Effect:
Soft minerals and may dissolve or disintegrate – pretreatment affects results

Soil texture by laser diffraction and hydrometer/sieving

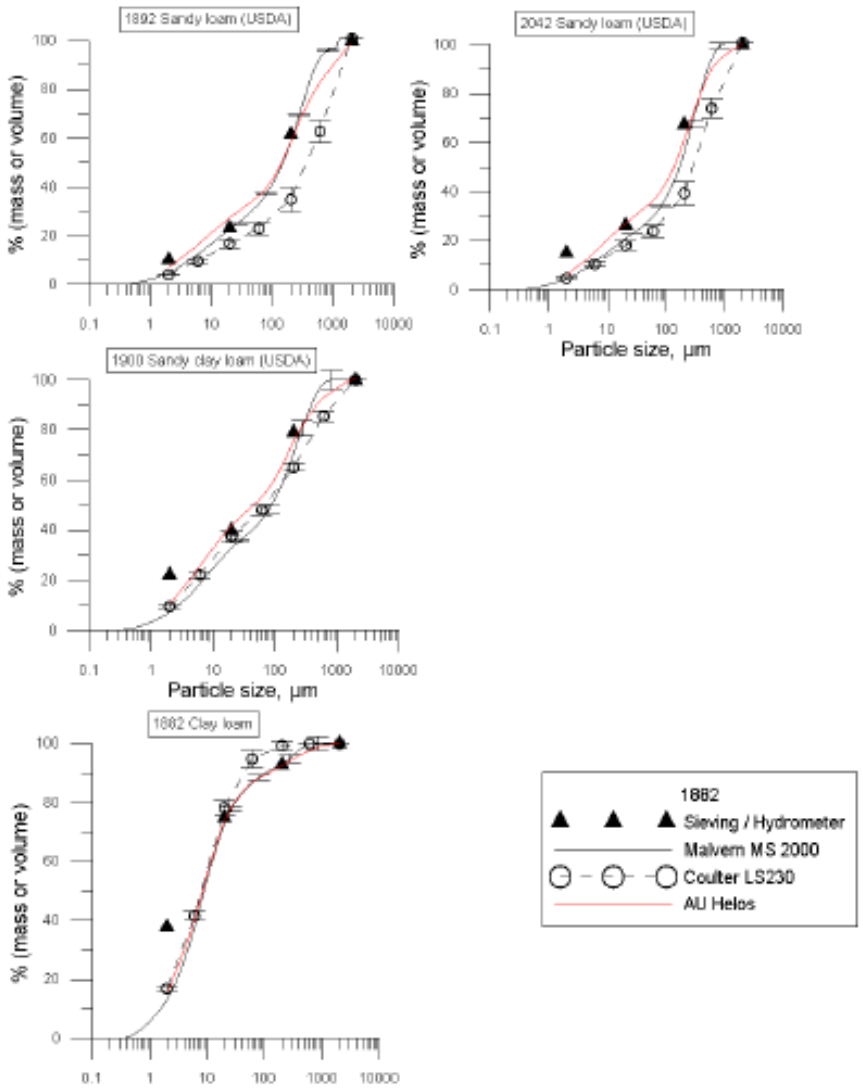


Figure 1 Comparison of three particle size laser instruments (pretreatment ultrasound 2 min full effect, no H_2O_2). On the Sympatec Helos, samples were wet separated and separates were measured on two lenses, These PSD's were constructed from 2 PSD's,

2. Three instruments, three different operating procedures

- **Small sample size – causing PSD uncertainty?**

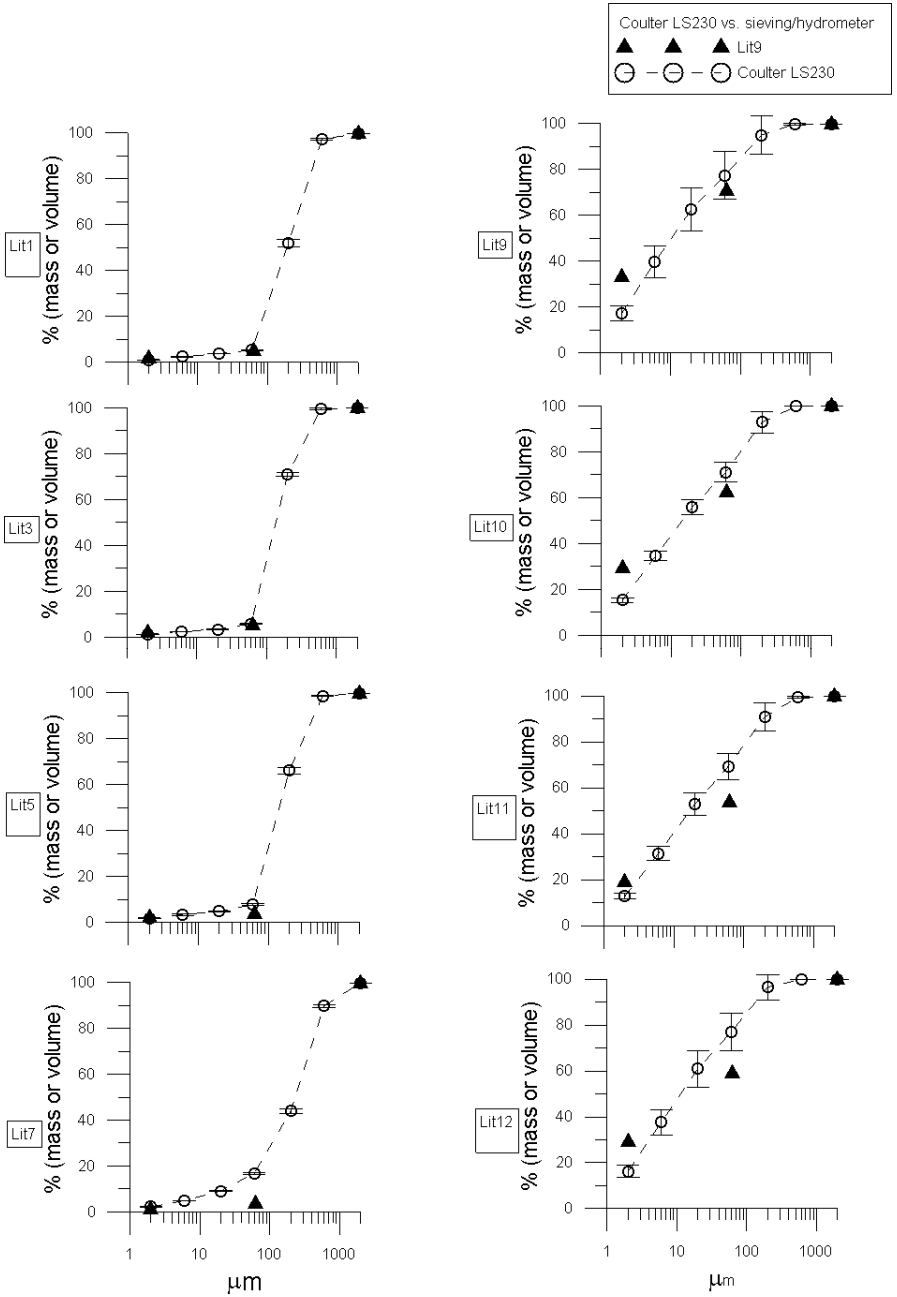
- *Sympatec Helos, Aarhus University*

- *Coulter LS30, Helsinki University*

- *Malvern Mastersizer 2000, University of Copenhagen*

Sample size most often 0.3 to 0.5 g.

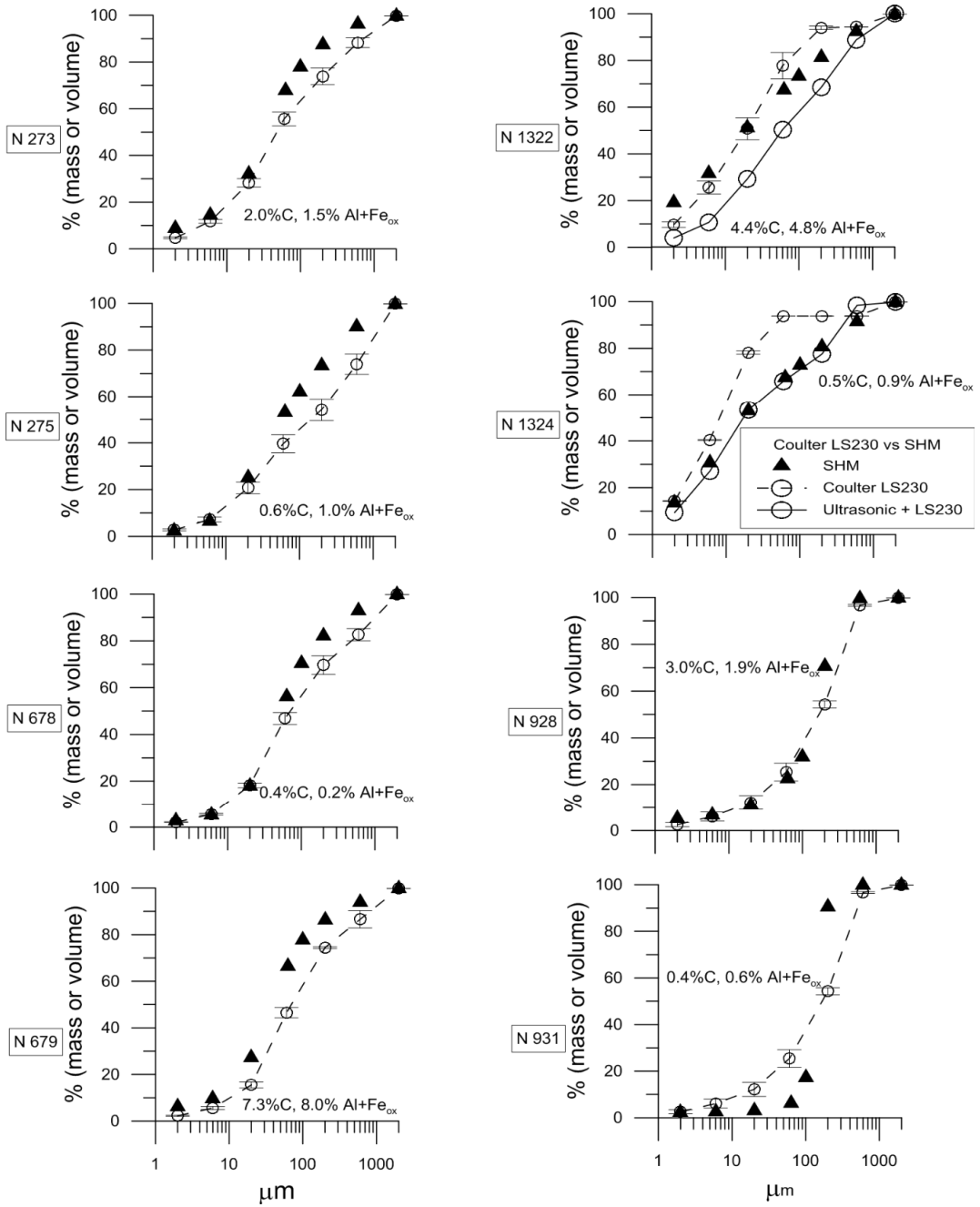
Repeatability good, due to 1 or 1.4 mm Sieving. Analysing only the 0-1 µm fraction.



Sedimentation vs. laser

Clay 2 µm – equivalency diameter

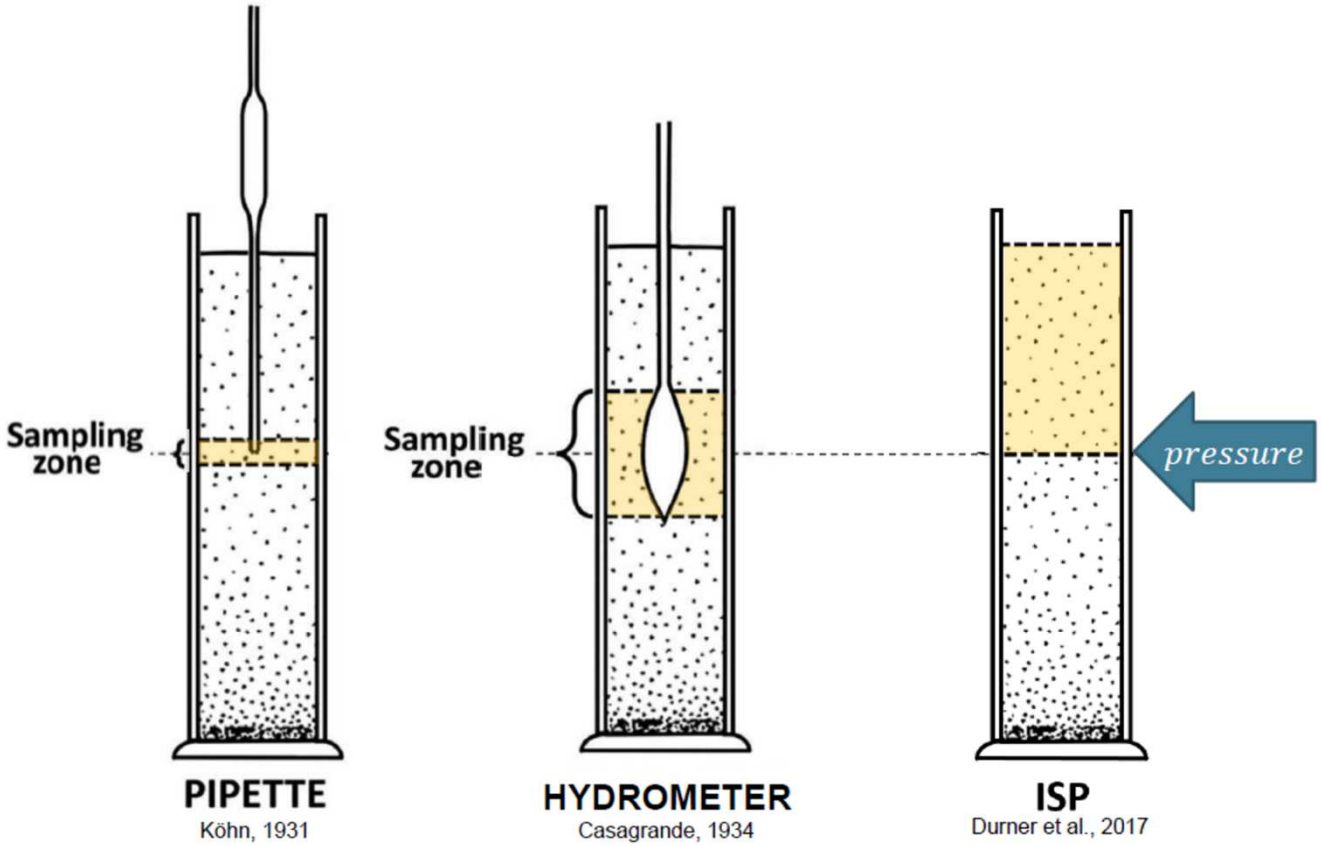
6 µm - used in Danish NFI on 300 samples (based on reference sample measurements, Callesen et al. 2019)



Coulter, Helsinki University, Soil samples from Norway – spodic material and heavy minerals

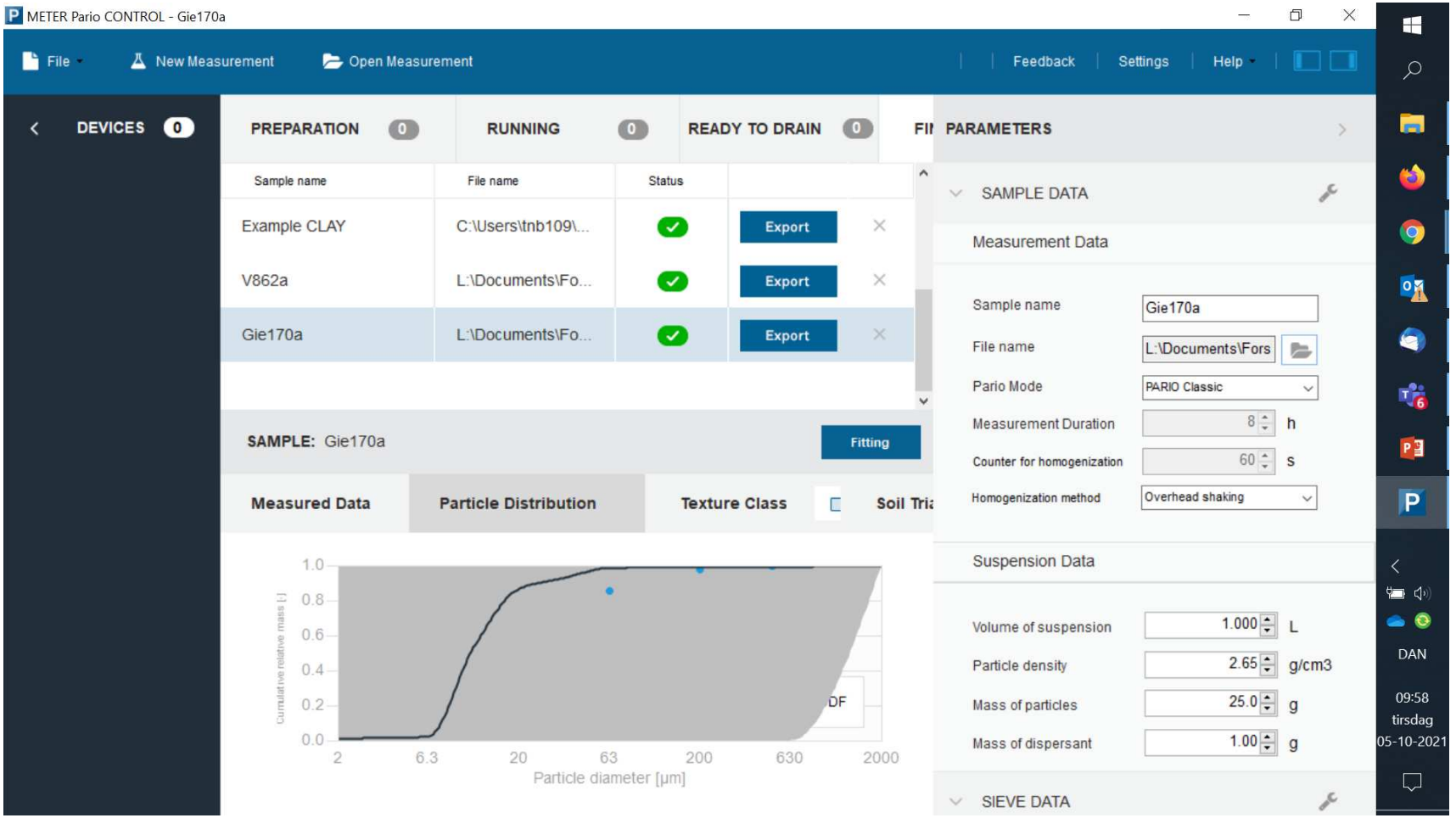
Texture issues:
Stokes law: $v = {}^{2}/_{9}(d_1 - d_2)gr^2/\eta$

d_1, density of minerals
$CaCO_3$, SiO_2 ,2.65 g cm^{-3}
heavy minerals, e.g. biotite avg 3.09 g cm^{-3}
$K(Mg,Fe^{2+})_3[AlSi_3O_{10}](OH,F)_2$



Durner, W., S.C. Iden, and G. von Unold (2017): The integral suspension pressure method(ISP) for precise particle-size analysis by gravitational sedimentation, *WaterResources Research*, 53, 33-48, doi:10.1002/2016WR019830 (open access).

Pario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File
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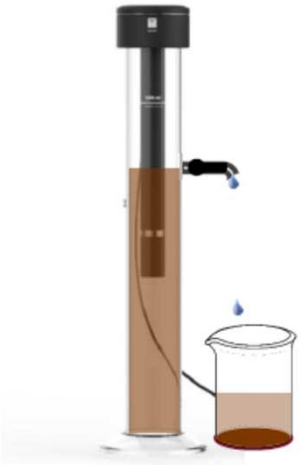
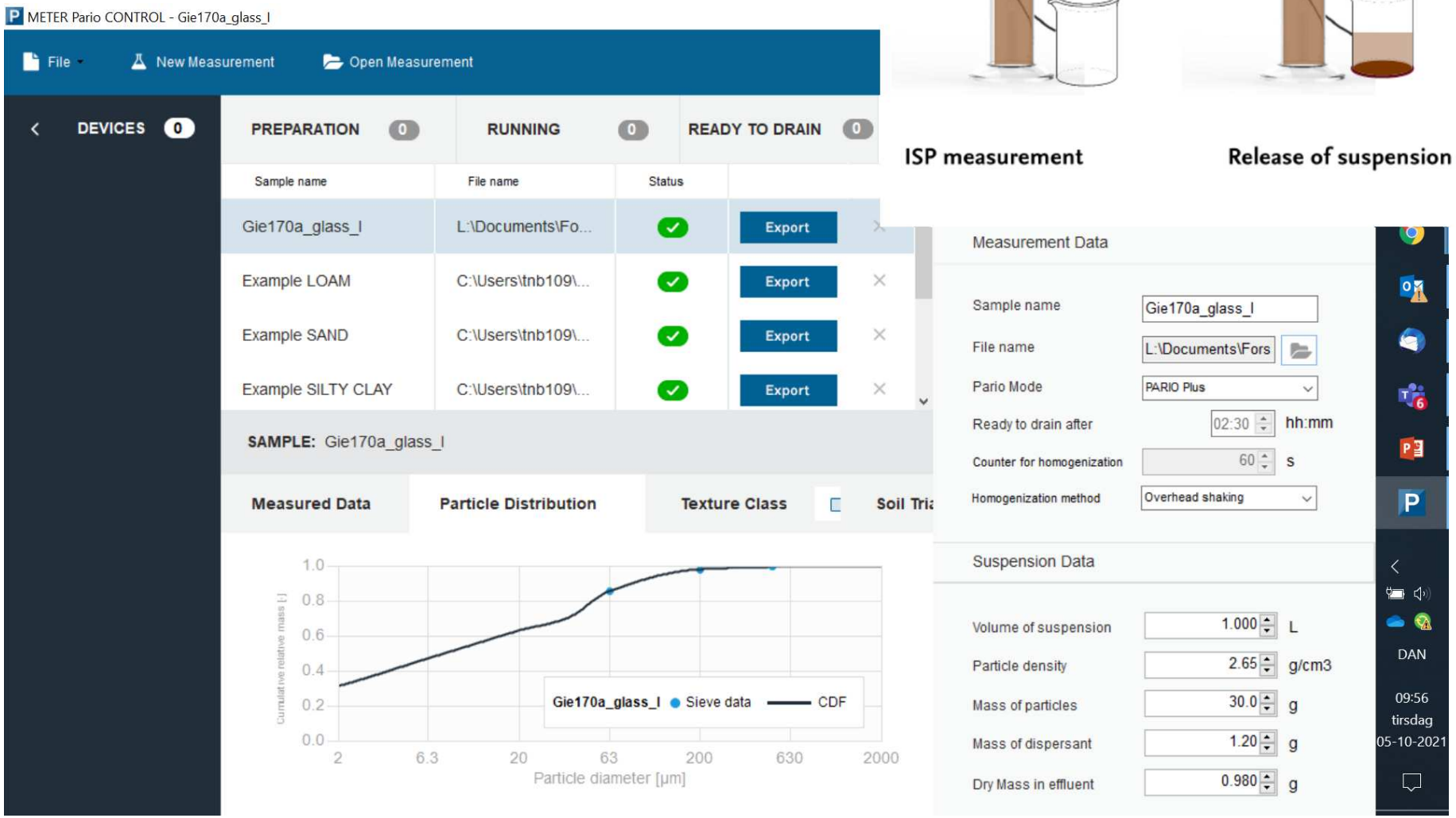
versus Pario+



ISP measurement **Release of suspension**



Conclusion

- Different approaches to pretreatment at different labs – soil geography
- Still various methods for measuring soil texture – very different analytical principles
- Knowledge of soil constituents and pretreatment effects is important – humus, lime, spodic material, volcanic material
- Laser diffraction can yield instrument and set-up specific results – great for large number of samples, but remember calibration against reference samples.
- Pario+ is a viable alternative. Capacity at UCPH is 2-4 per day – learning activity.