METOS®
BY PESSL INSTRUMENTS

METOS TSM

Non-contact, high-resolution soil mapping for improved irrigation and precision farming

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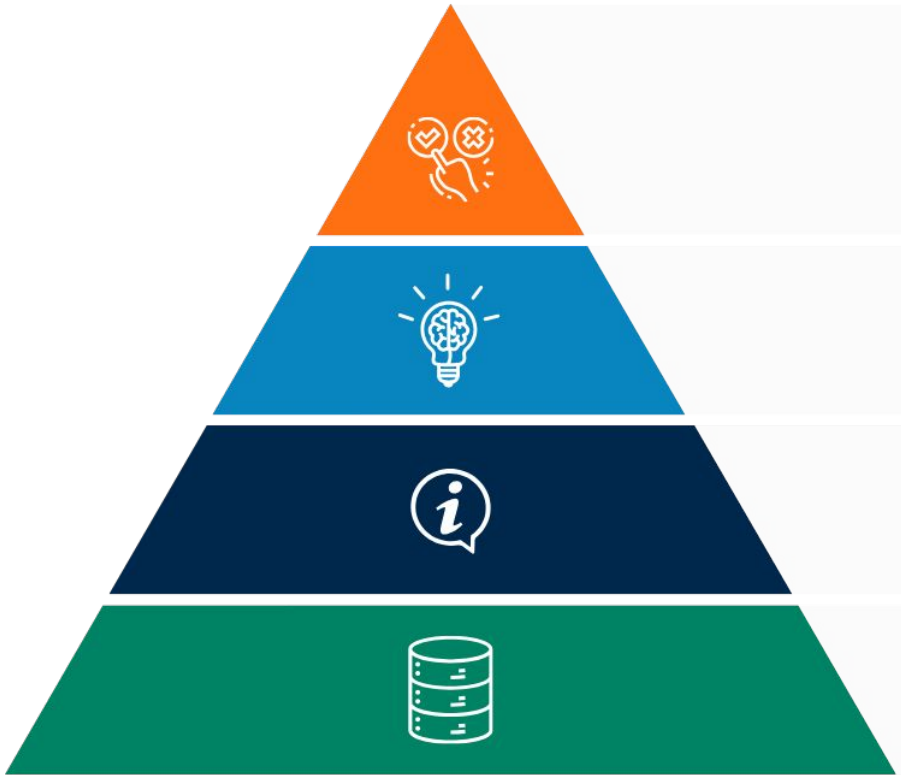
Value proposition

DECISIONS MADE EASIER AND TRANSPARENT



Better Decisions about agricultural processes such as irrigation, sowing and soil cultivation

Knowledge about agricultural contexts through expert know-how and experience

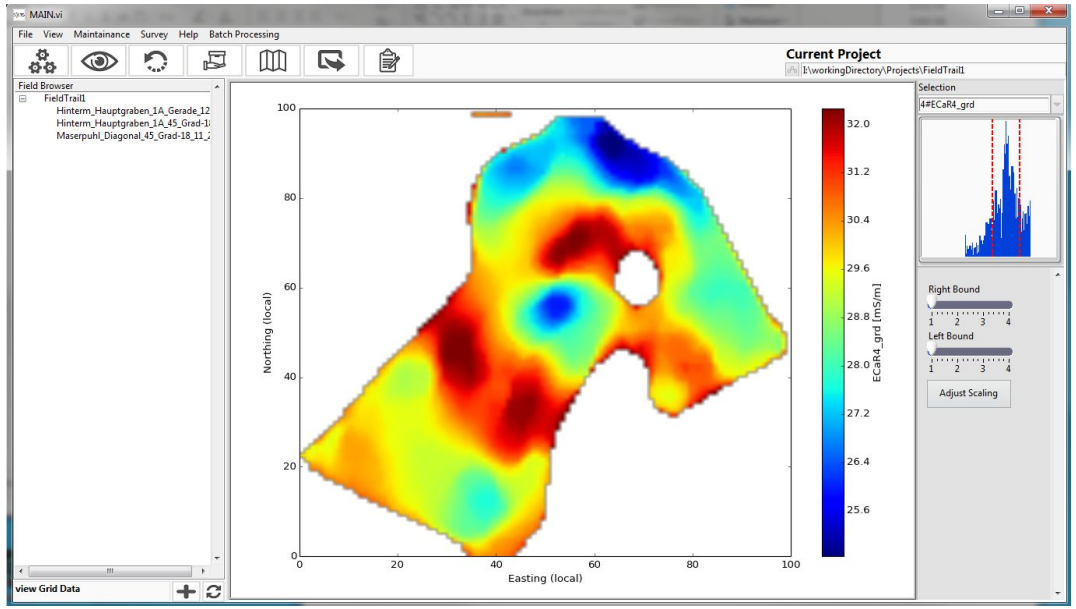
Information is created by algorithms and models and AI in combination with other data

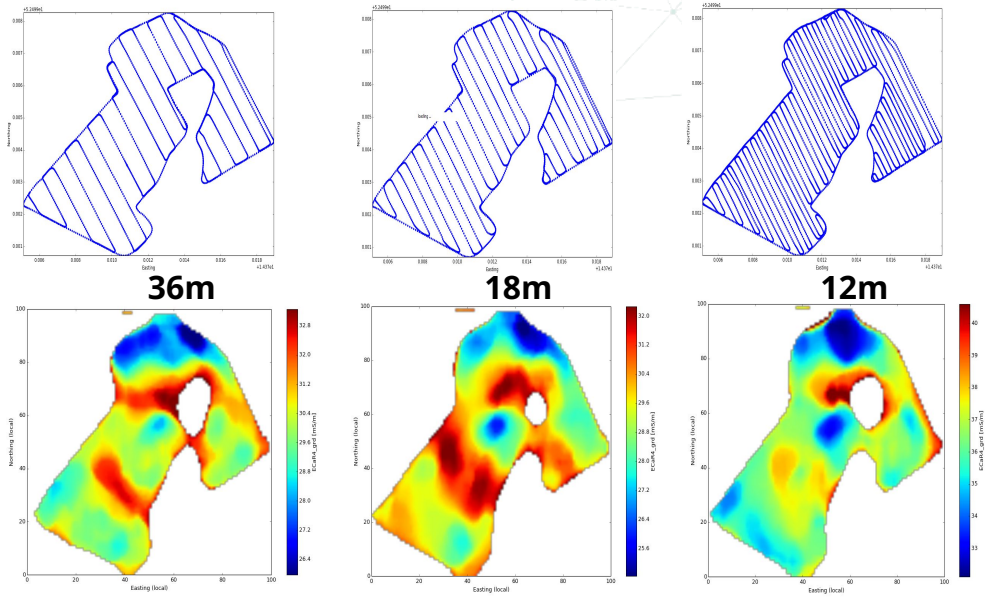
Data is collected and stored by sensors in the field and in the cloud

Soil parameters with dependence on the measurand conductivity extracted by METOS TSM

- **Salinity**
- **Soil related parameters**
  - **Soil texture**
  - **Soil water content**
  - Soil horizons and vertical discontinuities
  - Nitrogen content
  - Cation exchange capacity (CEC)
  - Organic residues
- **Specific agricultural parameters**
  - **Soil samples layout**
  - **Soil zones Boundaries**
  - **Compaction**
- **Other**
  - geological disturbances

Goal of mapping: get a comprehensive picture of the soil





Example from „METOS TSM Cloud", ECa mapping

Based on the pattern and distances scanned data resolution might be more precise – all values in between are calculated (interpolated)

What is the measurand … what data gets information?

… and what comes out in the end?

Measured Variables

ECa R1
ECa R2
ECa R3
ECa R4
iP R1
iP R2
iP R3
iP R4
iH1,
iH2
Roll,
Pitch

MODEL

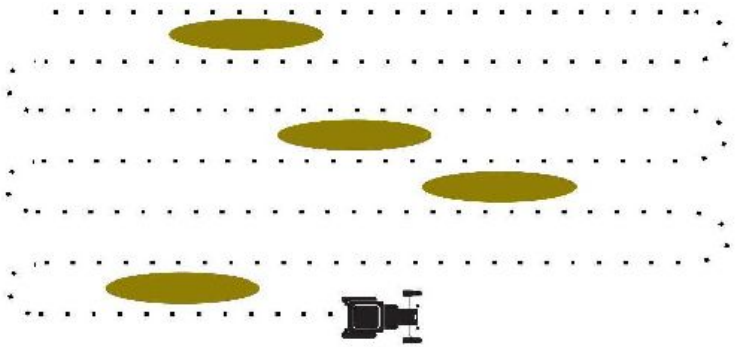
Parameters Received

ECt1, ECt2
Compaction
Texture
real. Water

mathematical context

$$\mathbf{E}_{By}(\mathbf{r},\mathbf{r}_1) = -\frac{\omega\mu_0 m_y}{4\pi}$$
$$\left\{\left[\frac{1}{\rho_1^2} - \frac{z+h}{\rho_1^2|\mathbf{r}-\mathbf{r}_1|} - \frac{2(y-y_1)^2}{\rho_1^4} + \frac{2(z+h)(y-y_1)^2}{\rho_1^4|\mathbf{r}-\mathbf{r}_1|} + \frac{(z+h)(y-y_1)^2}{\rho_1^2|\mathbf{r}-\mathbf{r}_1|^3}\right]\mathbf{i} + \right.$$
$$\left.\left[\frac{(x-x_1)(y-y_1)}{\rho_1^2}\left(\frac{2}{\rho_1^2} - \frac{2(z+h)}{\rho_1^2|\mathbf{r}-\mathbf{r}_1|} - \frac{z+h}{|\mathbf{r}-\mathbf{r}_1|^3}\right)\right]\mathbf{j}\right\}$$

Use case: location of soil sampling?



METOS TSM is scanning the field in tram lines in between 5 - 30 meters and data of where a representative location of soil sampling will be defined based soil types and differences.

Questions answered against traditional way:

- Better accuracy
- Better precision
- More representative sample

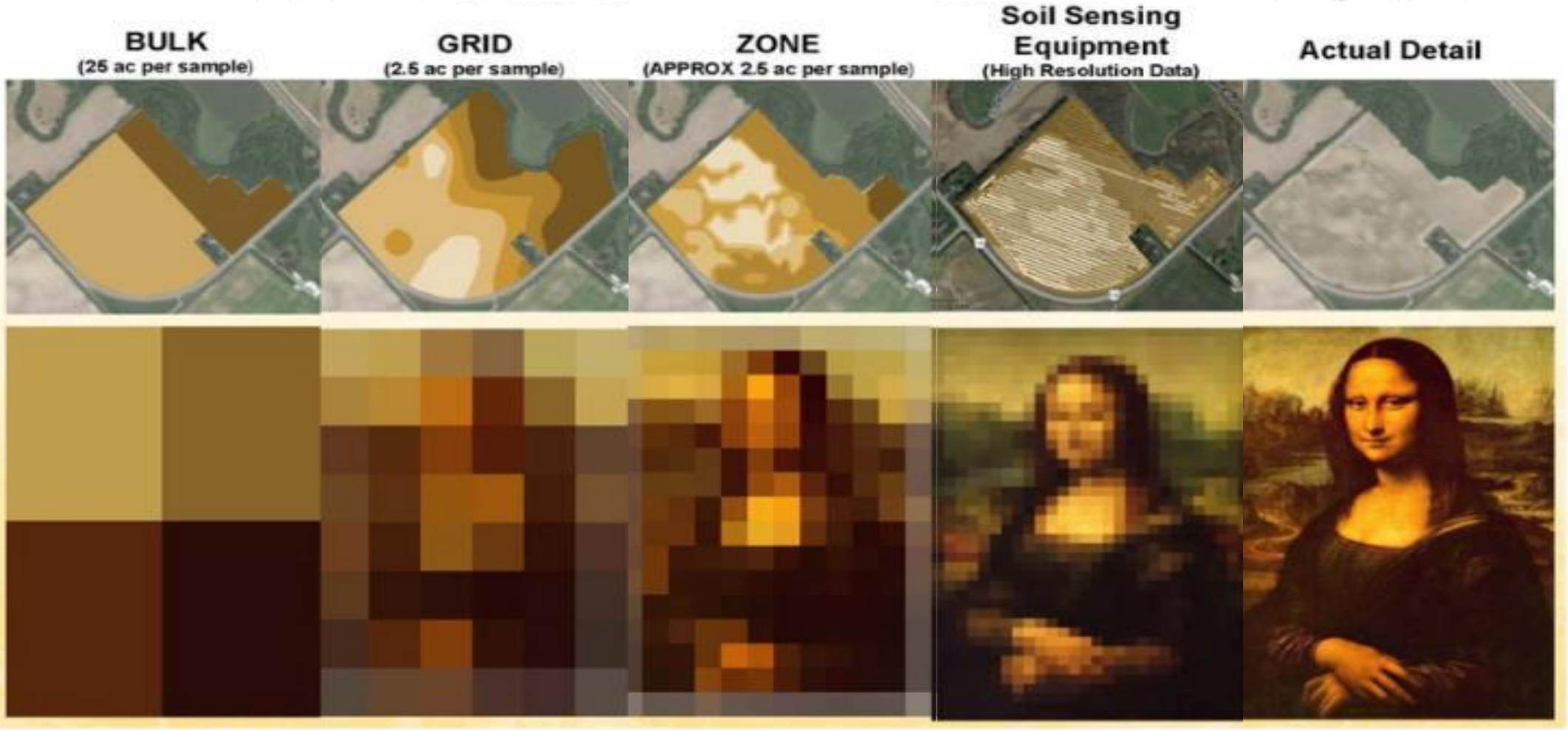
= Better data

Conclusion - What can I see?

- The tram line spacing determines the size of the zones that can be resolved.
- **Rough calculation**: the size of a zone is three times the tramline distance (e.g. tramline distance 3 m → zone size min. 9 m).
- Massive linear objects in the data indicate resampling fragments and have no relation to the ground.
- The driving speed usually has no influence on the lateral resolution.

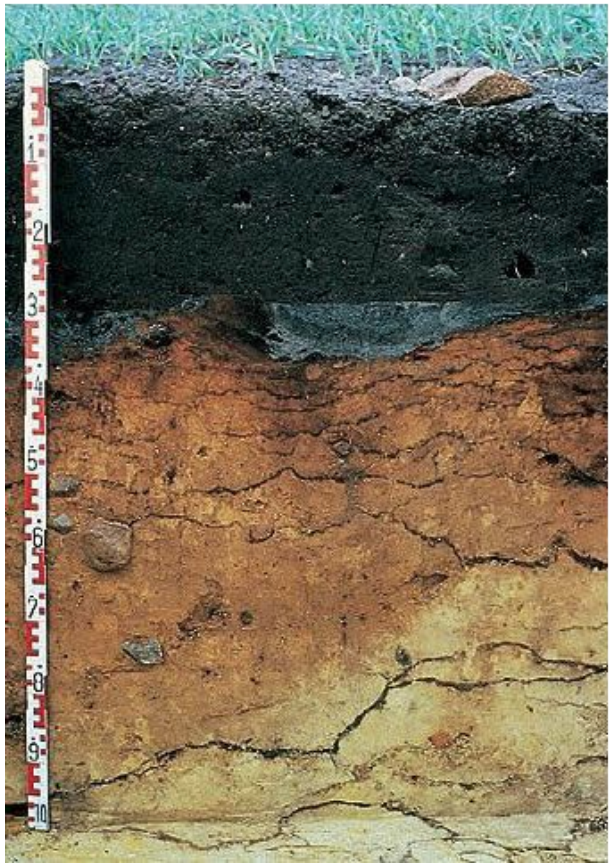
Conclusion - What can I see?

Example of the resolution of the soil mapping



How deep can I see into the ground?

Requirement: variability in the substrate



How deep can I see into the ground?

Considerations for vertical resolution

A **high contrast** between adjacent soil layers allows a stable inversion solution.

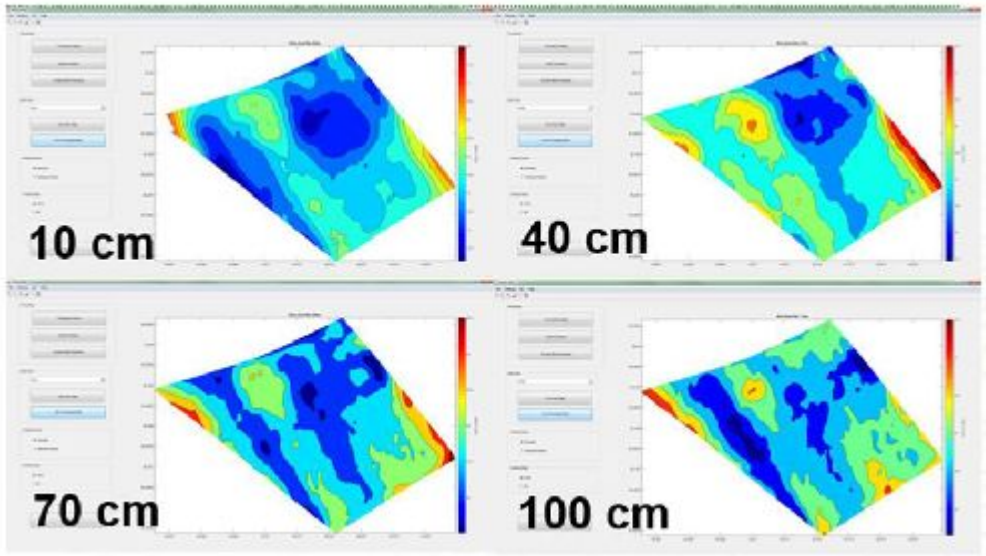
How deep can I see into the ground?

Considerations for vertical resolution

A **low** contrast between the soil layers leads to an uncertain inversion process. The results have a larger "error indicator" in the meta information.

How deep can I measure?

Depth range:

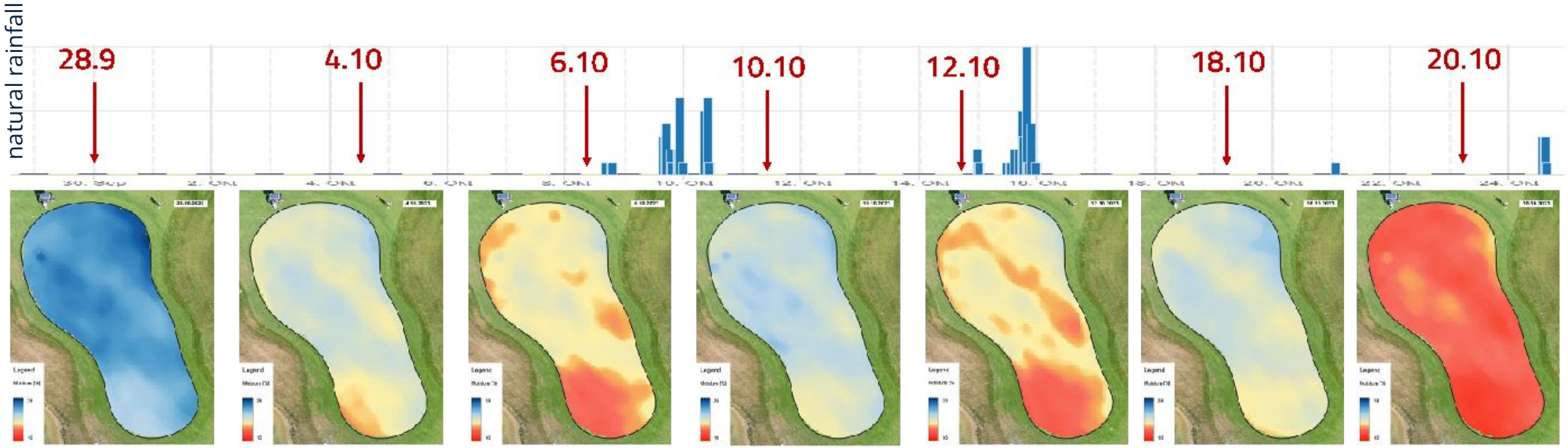


- 4 different levels: 0-25 cm, 15-60 cm, 55-95 cm and 85-115 cm (with overlap between levels).
- Eca values for each level
- Maximum embedding depth: 1.1m

Time Series on a Golf Green as an example

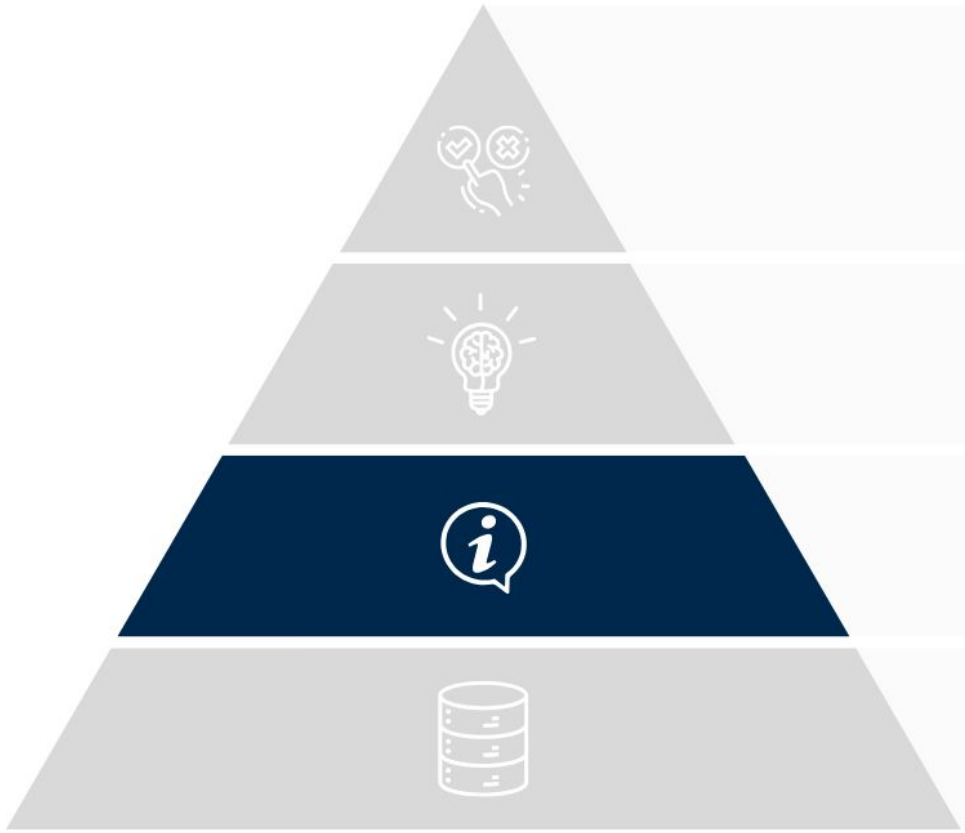
Moisture Mapping

Time series provide an up-to-date snapshot of the current moisture situation and a forecast of future irrigation requirements.



Our solution?

To generate information!



Better Decisions about agricultural processes such as irrigation, sowing and soil cultivation

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METOS TSM Client Cloud

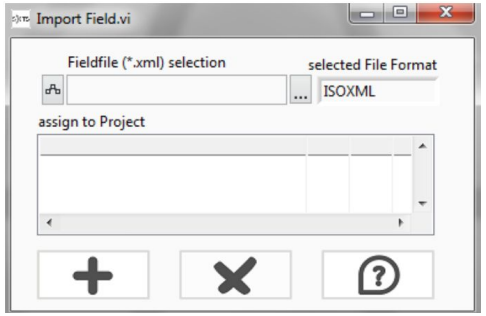
YES WE PROCESS SOIL MAPS!

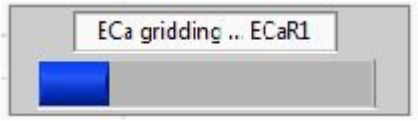
- **Automatic data analysis and visualization**
- **Data immediately available**
  - No delay due to data post-processing!

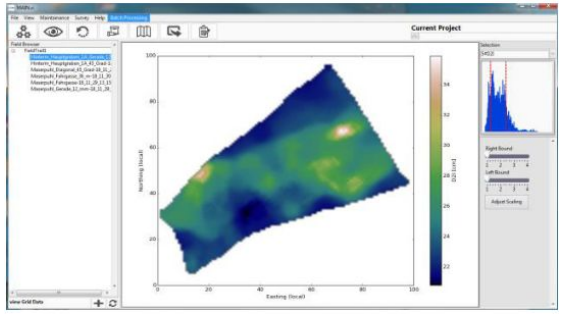
- **Available soil information:**
  - <u>Soil data per depth:</u>
    - raw EC per depth
    - conductivity map per depth
  - <u>Soil information:</u>
    - Soil zones
    - Layer boundaries
    - Relative water content

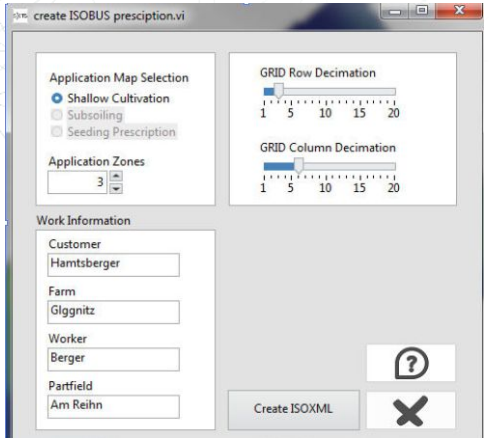
METOS TSM Client Cloud

DATA BECOMES INFORMATION









Import data	Process Eca Data	Generate Products (e.g. prescription maps)	Export data

Import as:

- TSM raw data
- ISOXML TASK DATA
- 3rd party format

Calculation as:

- single field
- or as a stack

Products

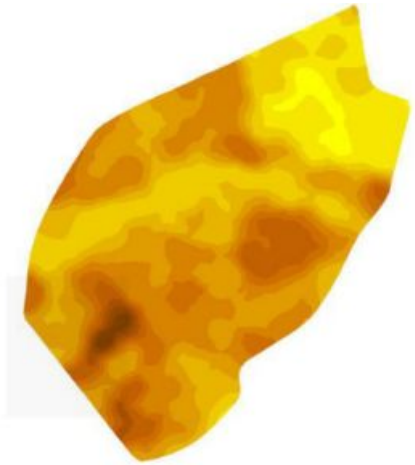
- Soil zones
- rel. water content
- layer boundary
- soil application
- seeding application

Export as:

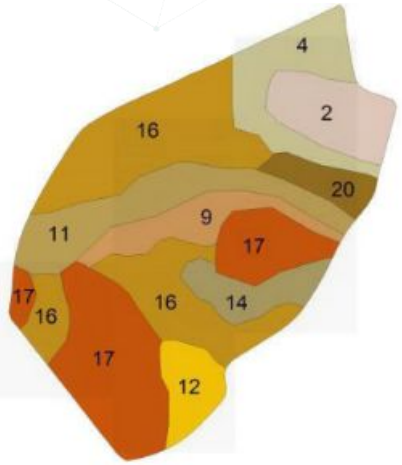
- GIS file (*.shp)
- or as ISOXML TASK

When is the appropriate time to scan my fields?

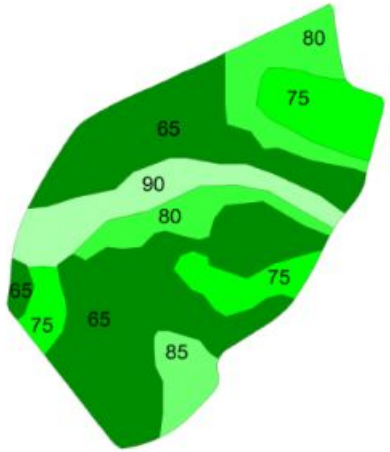
And how long will my data/information remain up-to-date?



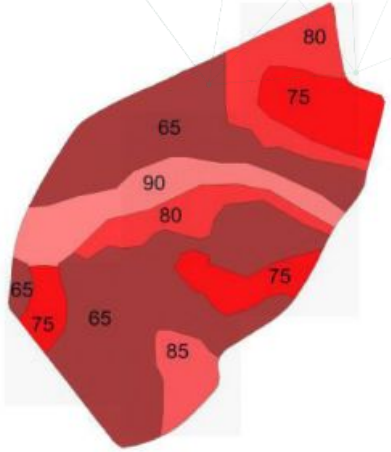
Conductivity display



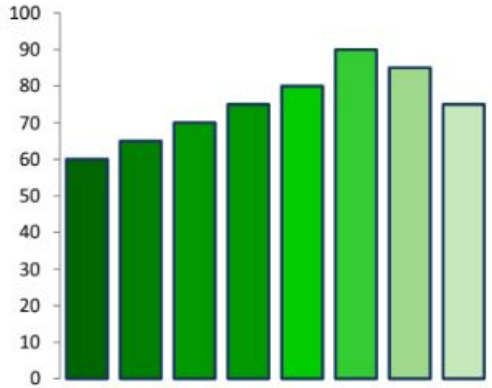
Soil types



% Fundamentals map

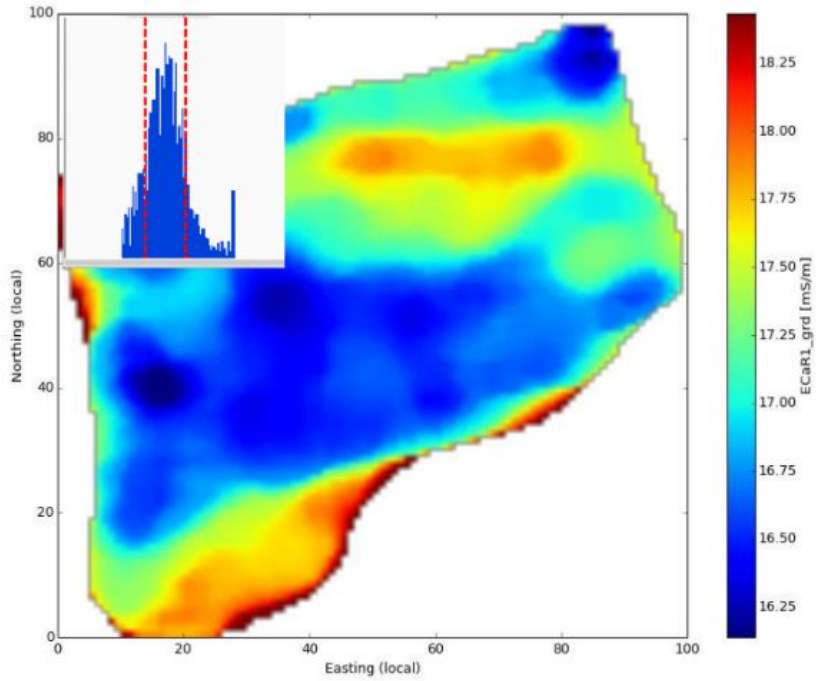


variable seeding planning

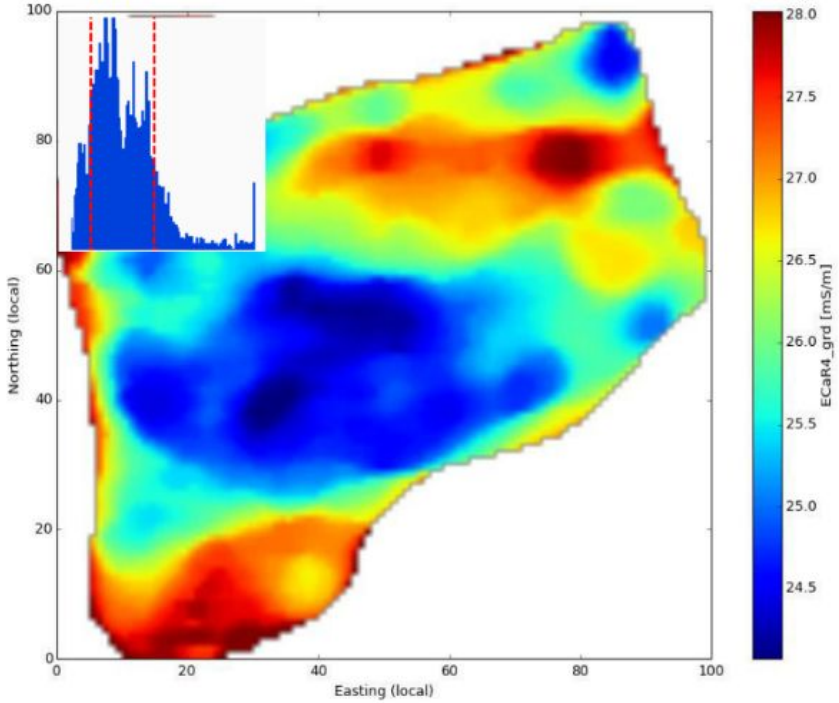


When is the appropriate time to scan my fields?

Data recording March 2017



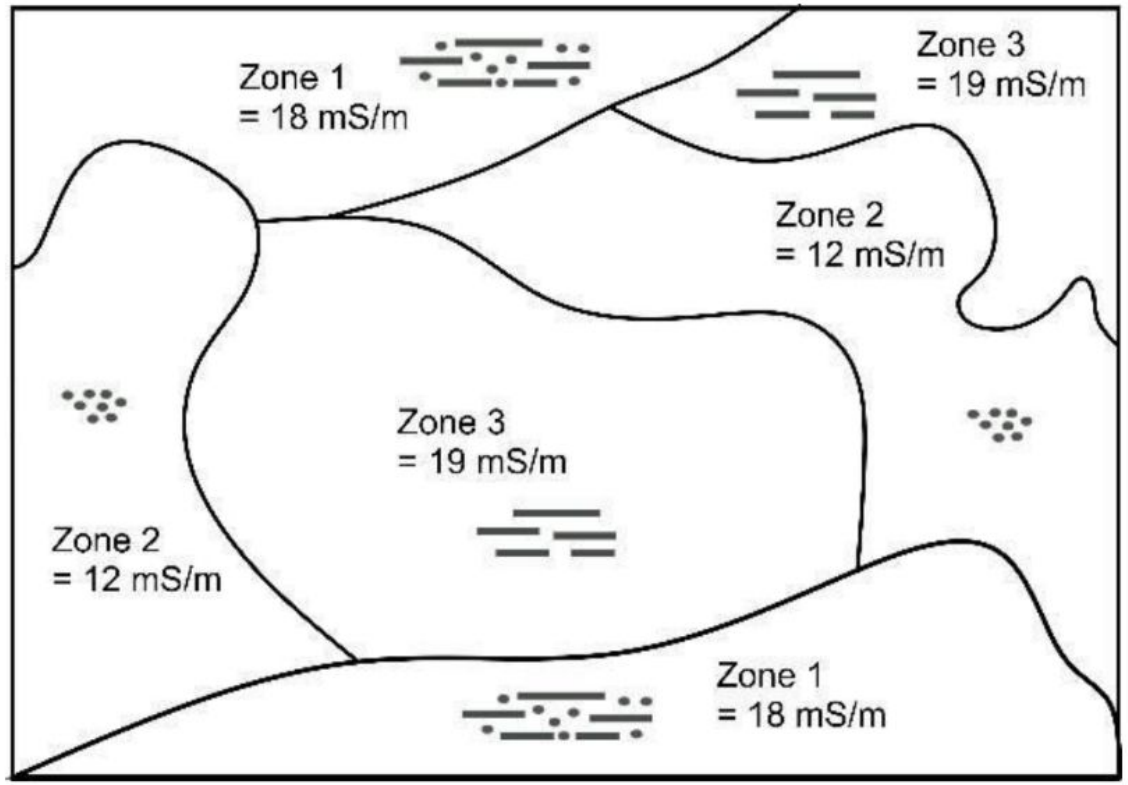
Data recording November 2018



- Zone shapes are retained, however
- The measured value range differs from the reference epoch

When is the appropriate time to scan my fields?

Significance for the creation of the application map - an illustrative example.



Data collection: autumn - dry summer, little available water

When is the appropriate time to scan my fields?

Evaluation on the application planning

EC Measurement	Evaluation	Application	EC Measurement	Evaluation	Application
Zone 2, 23 mS/m	58	273 Kg/Ha	Zone 2, 18 mS/m	72	262 Kg/Ha
Zone 1, 14 mS/m	35	350 Kg/Ha	Zone 2, 12 mS/m	48	329 Kg/Ha
Zone 3, 32 mS/m	82	254 Kg/Ha	Zone 3, 19 mS/m	76	261 Kg/Ha

- Assumptions:
  - Rating according to Tollner
  - min/max 220-360 Kg/Ha

Conclusion - When is the appropriate time to scan my fields?

- The least accuracy is lost if the mapping time is as close as possible to the application time.
- If this is not possible, the data collection should at least be in the same season as the application.
- Ideally, the data collection/calculation/application should take place at the same time.

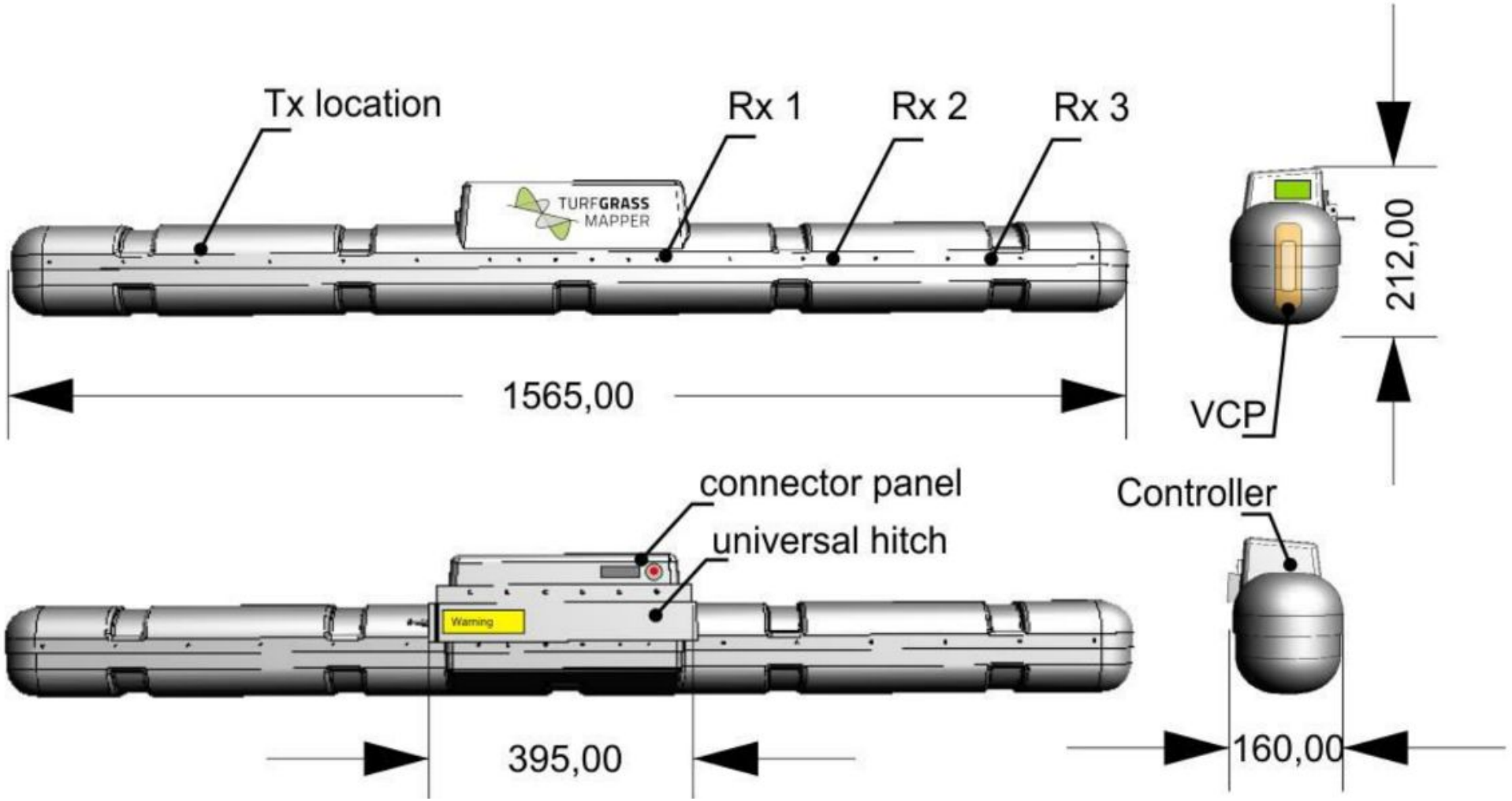
Conclusion - How deep can I see into the ground?

- With the METOS TSM, the calculation of the depth is based on the physical contrast.
- The configuration determines the maximum penetration depth
- Measurements are repeatable and reproducible.
- The human component is excluded from the interpretation of
- soil layer depths.

Technical Details: METOS TSM

Technology	Frequency Domain Electromagnetics
Frequency	6-12 KHz
Sampling Rate	5 – 20 Hz
Vertical sampling	2 – 4 dedicated depth
Max DOE*	75 cm
Width	156 cm = 61.41“
Weight	9 kg
Material/colour	ASA/ABS, RAL 7016
Interfaces	RS232, WLAN, CAN
Positioning	GPS (internal/external) TTL input, 1pps trigger

Dimensional Drawings



Comparative Measurement methods – Pros/Cons:

DATA COLLECTION METHODS

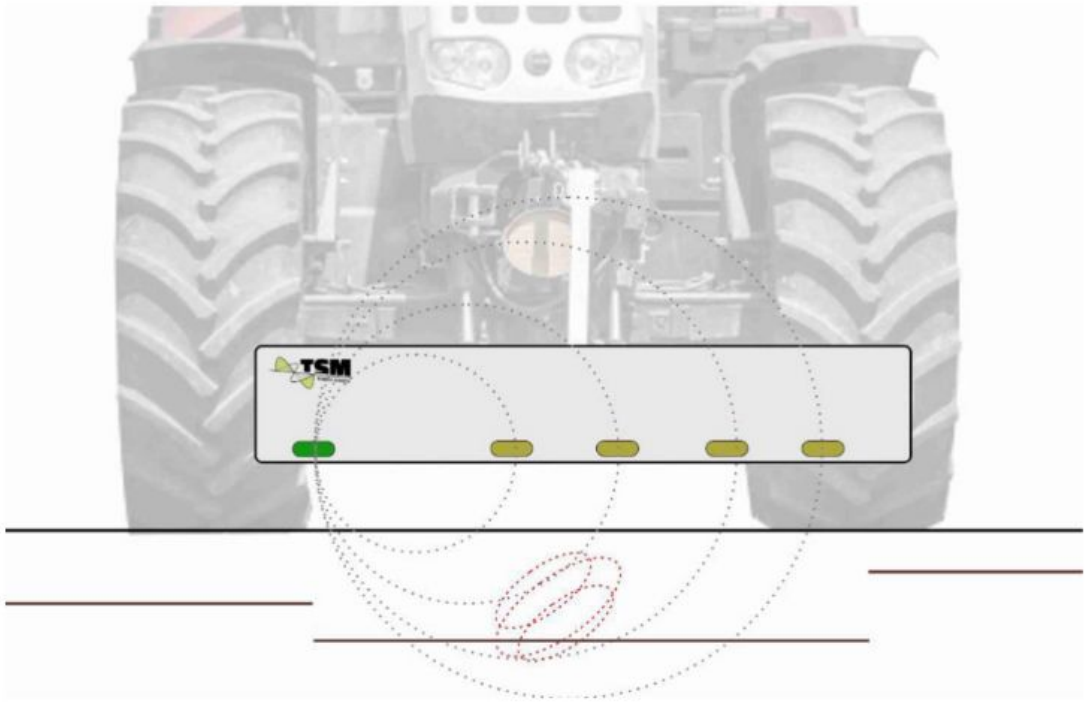
- Aircraft/drones based remote sensing
- Satellite based remote sensing
- Spectroscopy
- Electromagnetics
- Resistivity measurement
- Ground radar

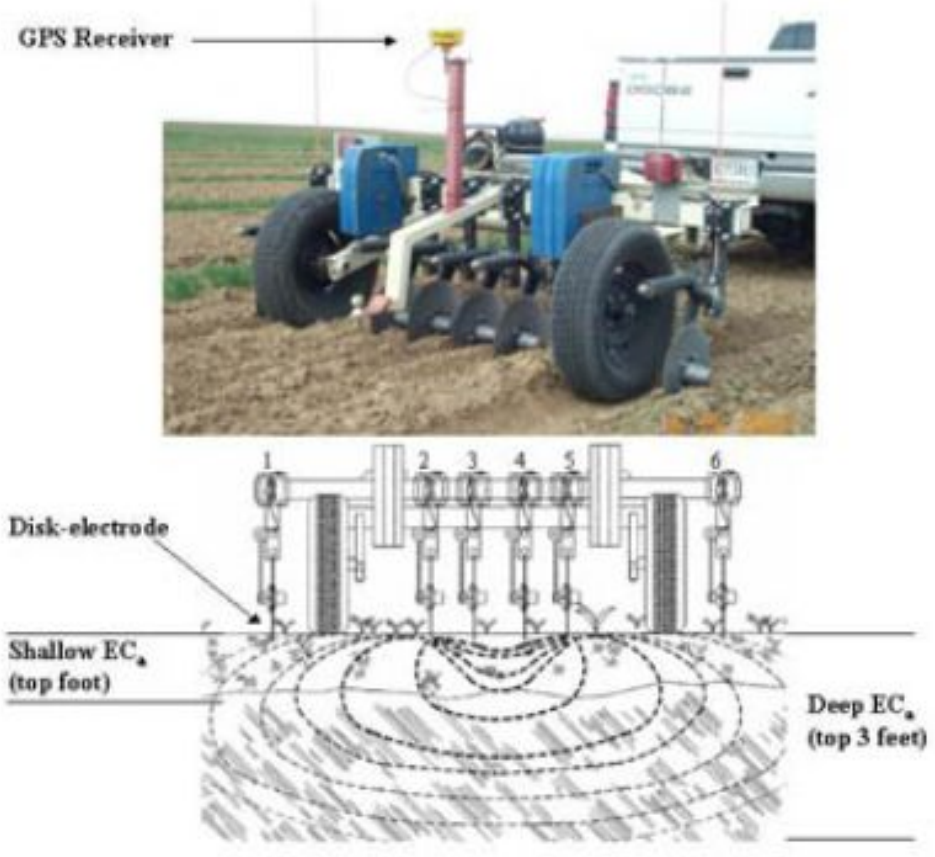
Technical Details: METOS TSM

	EM38	DualEM	Veris	METOS TSM
Installation	towed	towed	towed	vehicle mounted
Weight	5.4 kg	8 kg	544 kg	9 kg
Depths	1-2	1-6	2	4
Soil contact	Yes	Yes	Yes	No
Realtime	No	No	No	Yes
ISOBUS	No	No	No	No
Autonomous mapping	Yes	Yes	No	Yes
Implement Control	No	No	No	Yes

Induction - versus resistance measurement

Comparison of the measuring principles



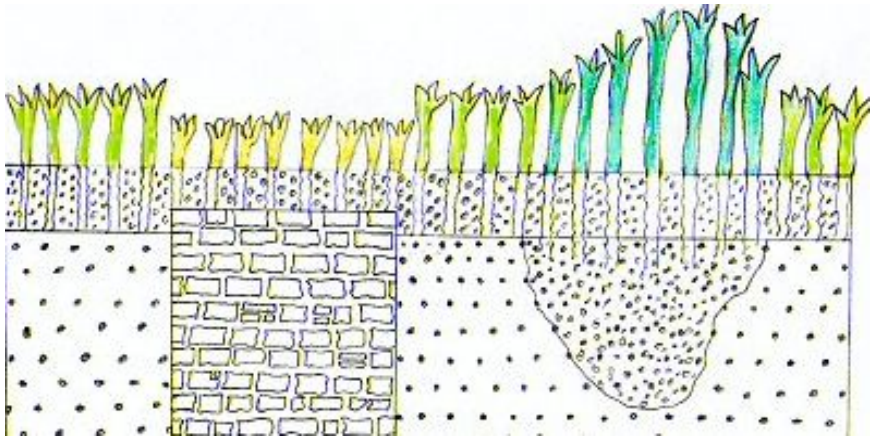


For specific occasion ...

Satellite data can do the same and are free - why do I need a METOS TSM?

Can satellites do the same as the METOS TSM?

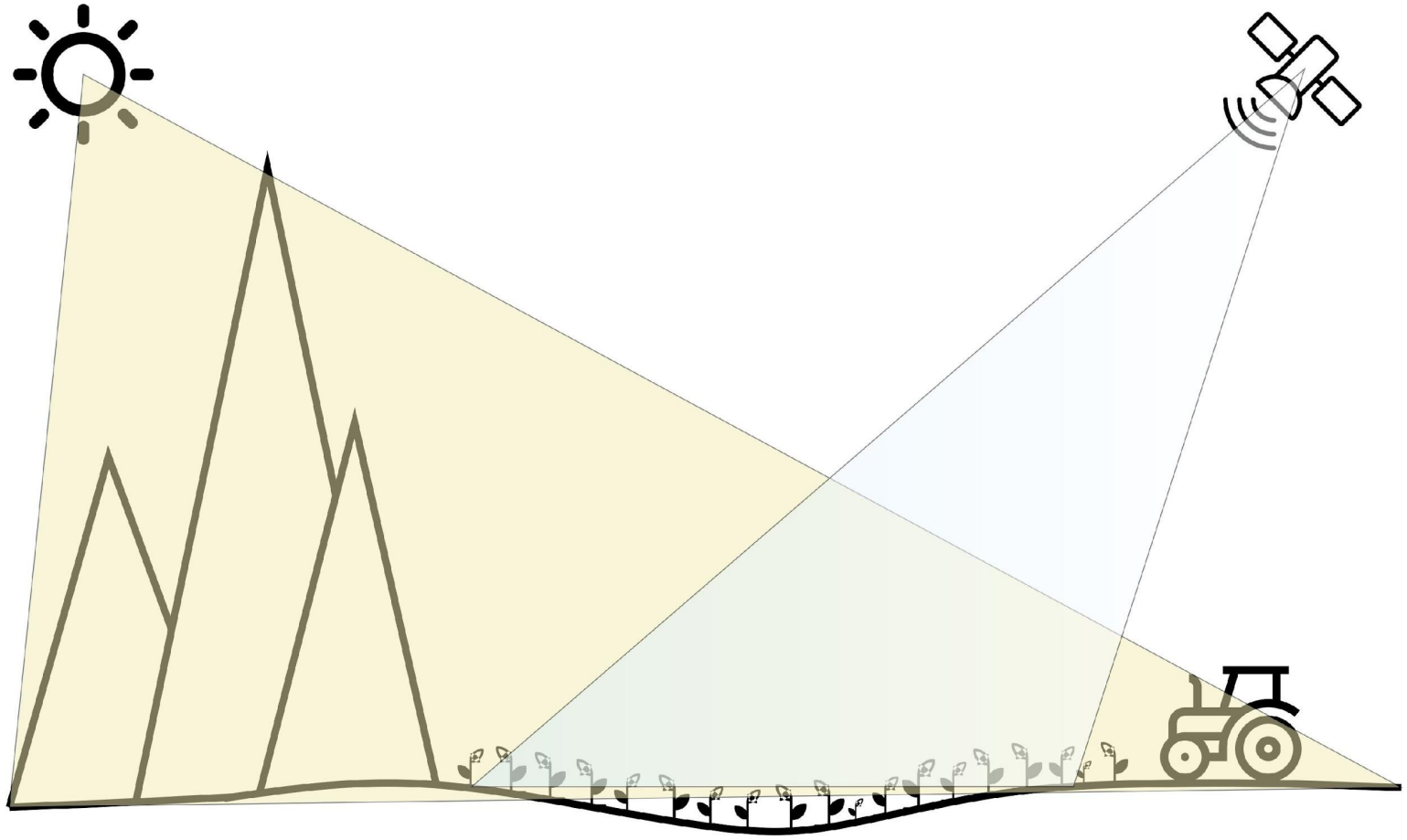
- Images from satellite / aircraft / drone depict the earth's surface
- Properties of the ground are represented at best by vegetation characteristics



no soil properties are measured

What can the METOS TSM do that satellites cannot?

Case 1 - Shadow through mountains / hills / topography

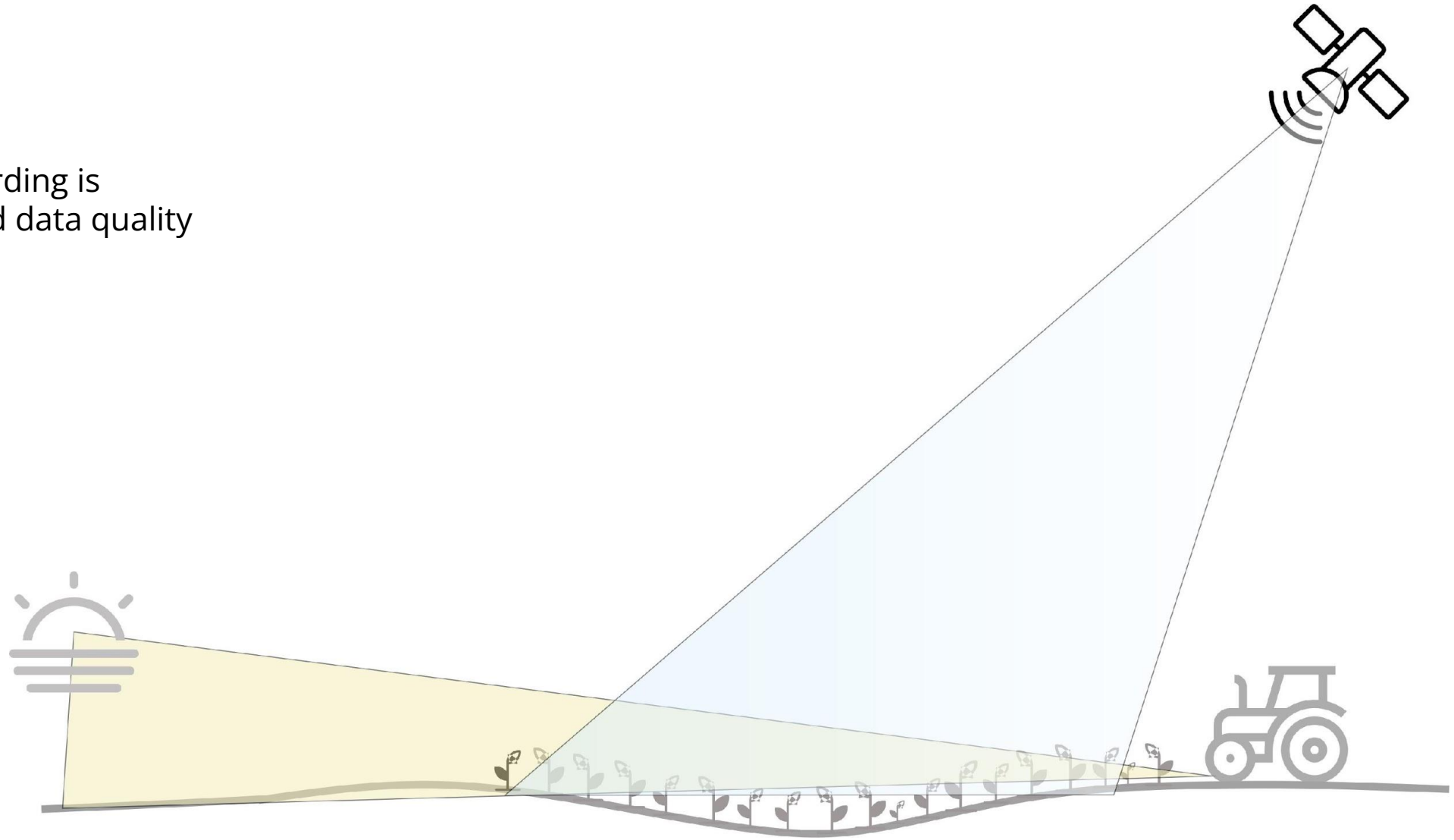


Consequence:
Topographic shadows interfere with the recording

What can the METOS TSM do that satellites cannot?

Case 1 - low sun

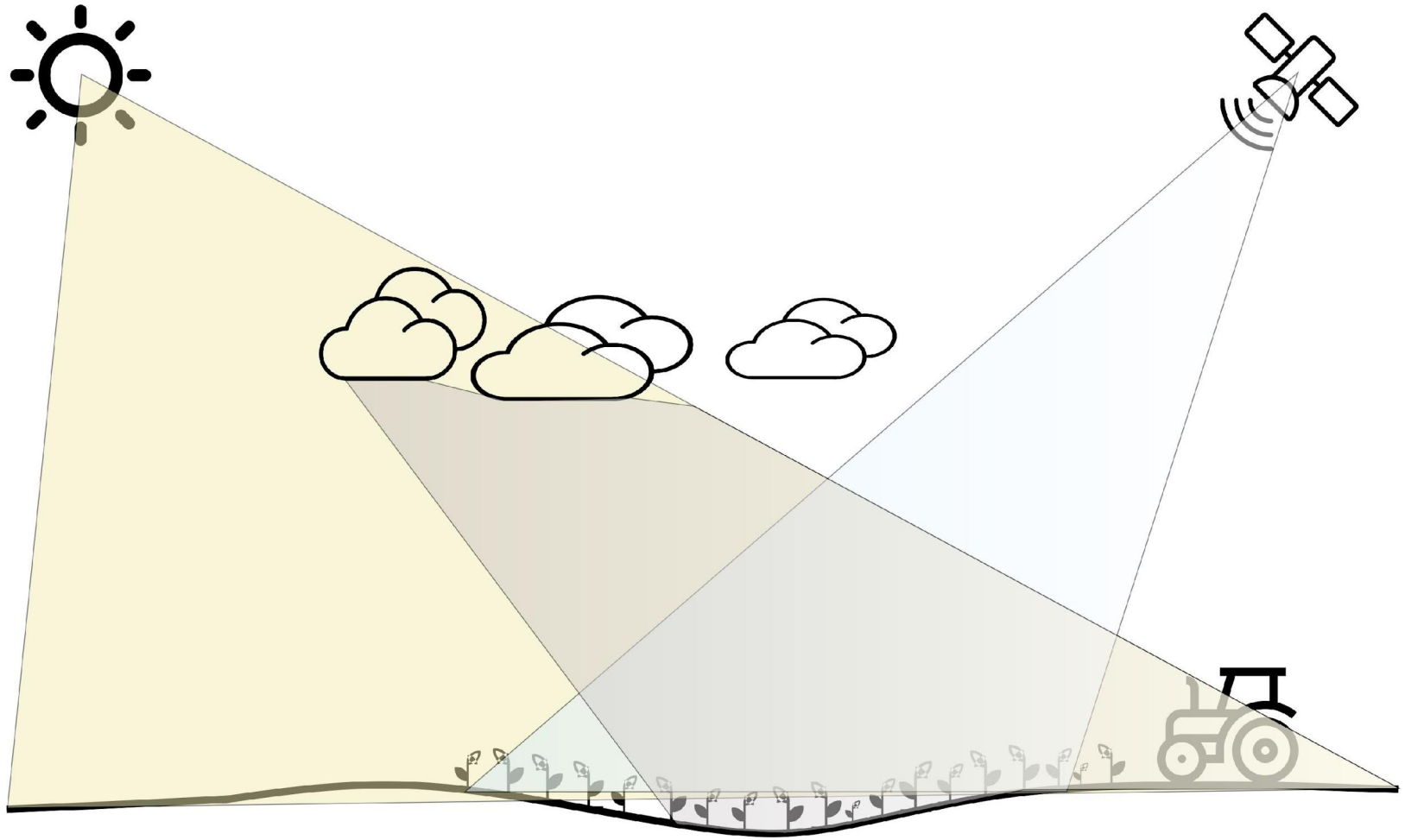
Consequence:
the time of recording is
decisive for good data quality



What can the METOS TSM do that satellites cannot?

Case 1 - Shadow through clouds / fog / haze

Consequence:
The quality of the remote sensing data is determined by the weather!



METOS TSM vs Satellite Data

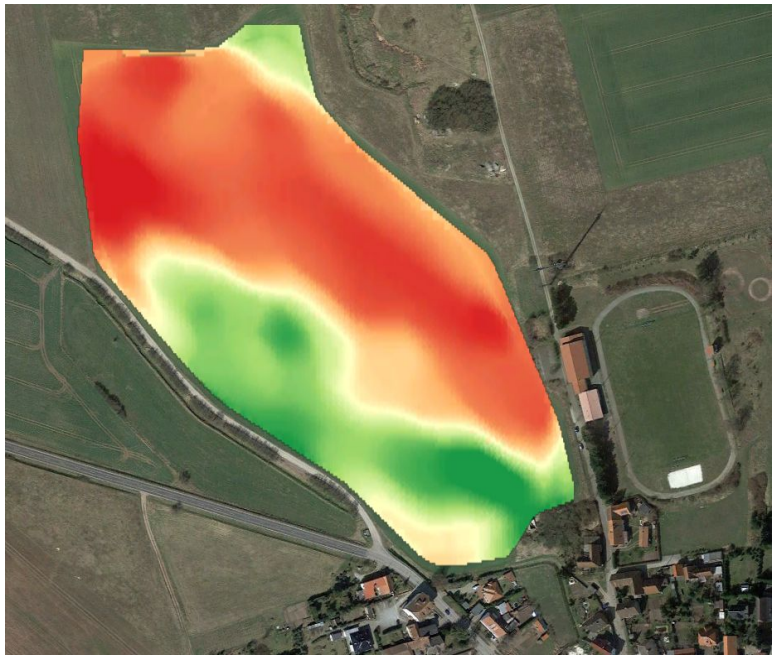
2 Technologies - 2 Applications

METOS TSM	Satellite information
Flexible and can be used at any time	Depending on certain shooting cycles, weather and lighting conditions
Provides a high level of detail on field scale	Quickly provides an overview of large areas
Information about the floor	Information about the surface
TSM provides information on soil properties at any time of the year	Soil indicators due to fouling characteristics are only visible at a very limited time of the year

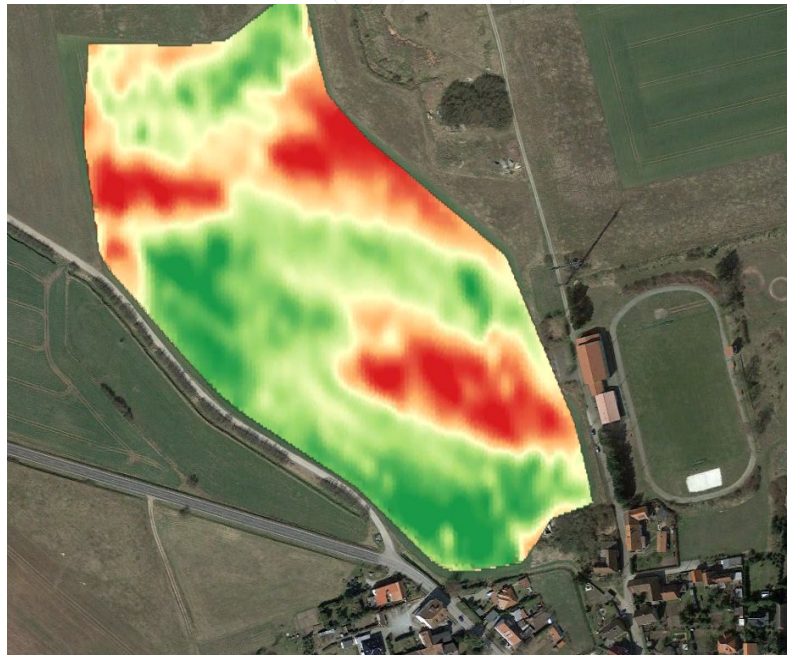
Are satellite data and METOS TSM data comparable?

YES AND NO.

Satellite image 2000



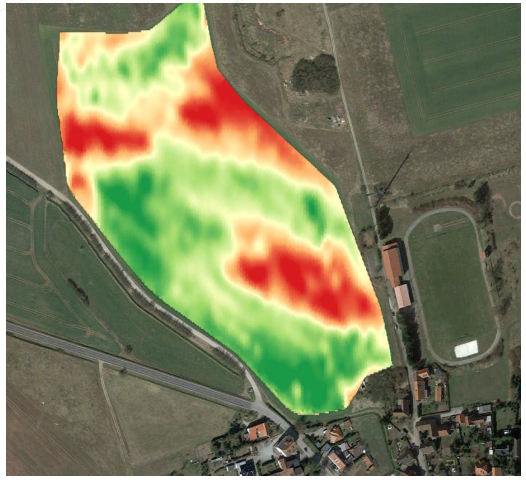
METOS TSM

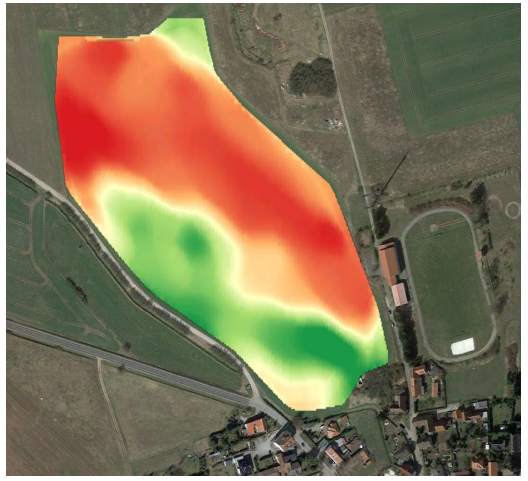


Yield Mapping

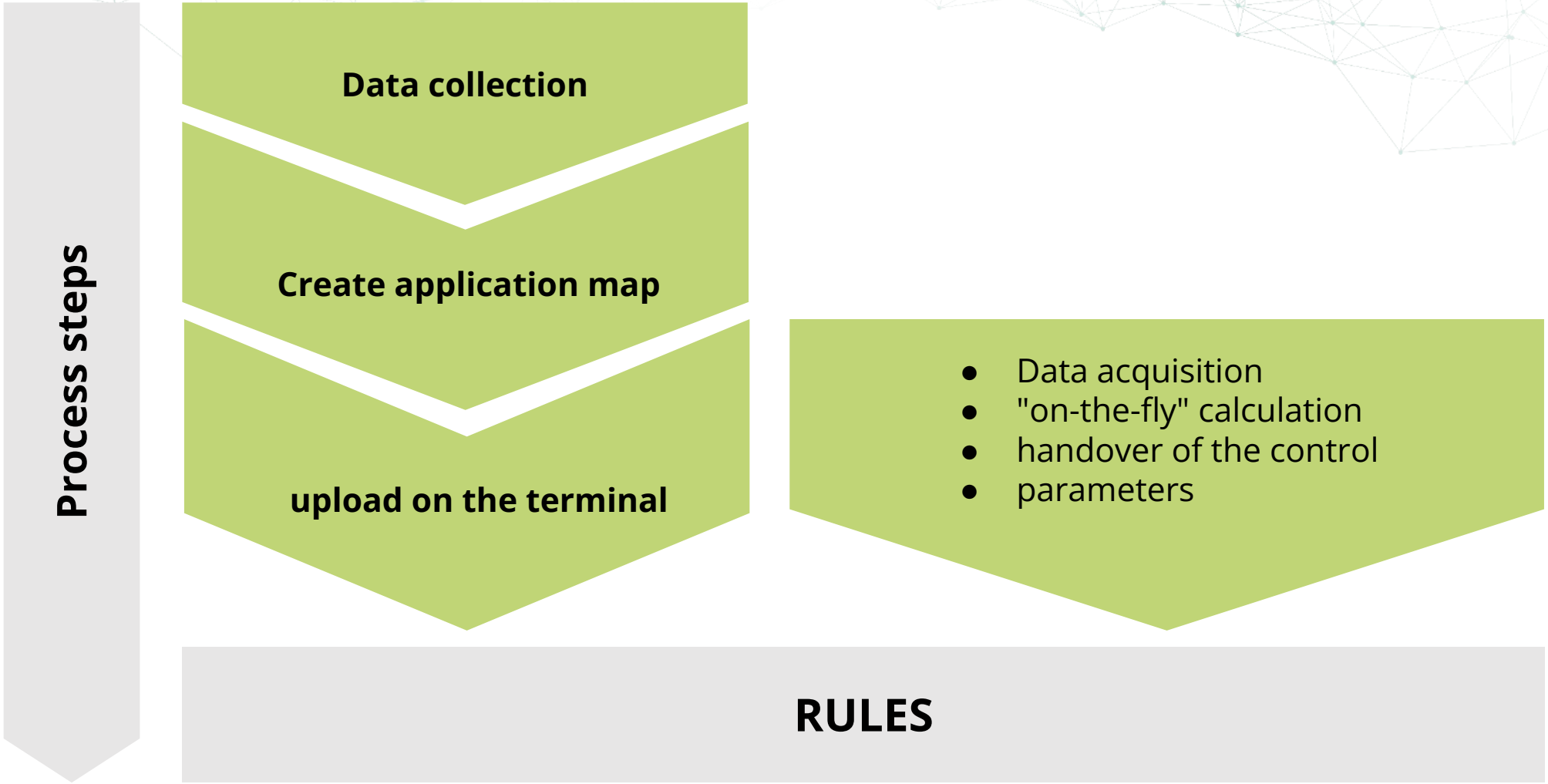
Are satellite data and METOS TSM data comparable?

YES AND NO.



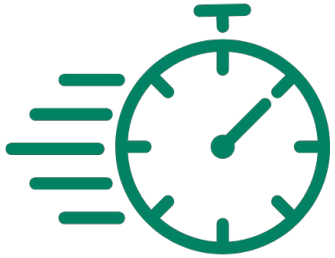


Alternative to mapping: machine control



Alternative to mapping: machine control

non-destructive technology



quick installation

a solution for sustainable agriculture

real-time capable

More Information needed?

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https://metos.global/en/metos-tsm/

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Pessl INSTRUMENTS

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