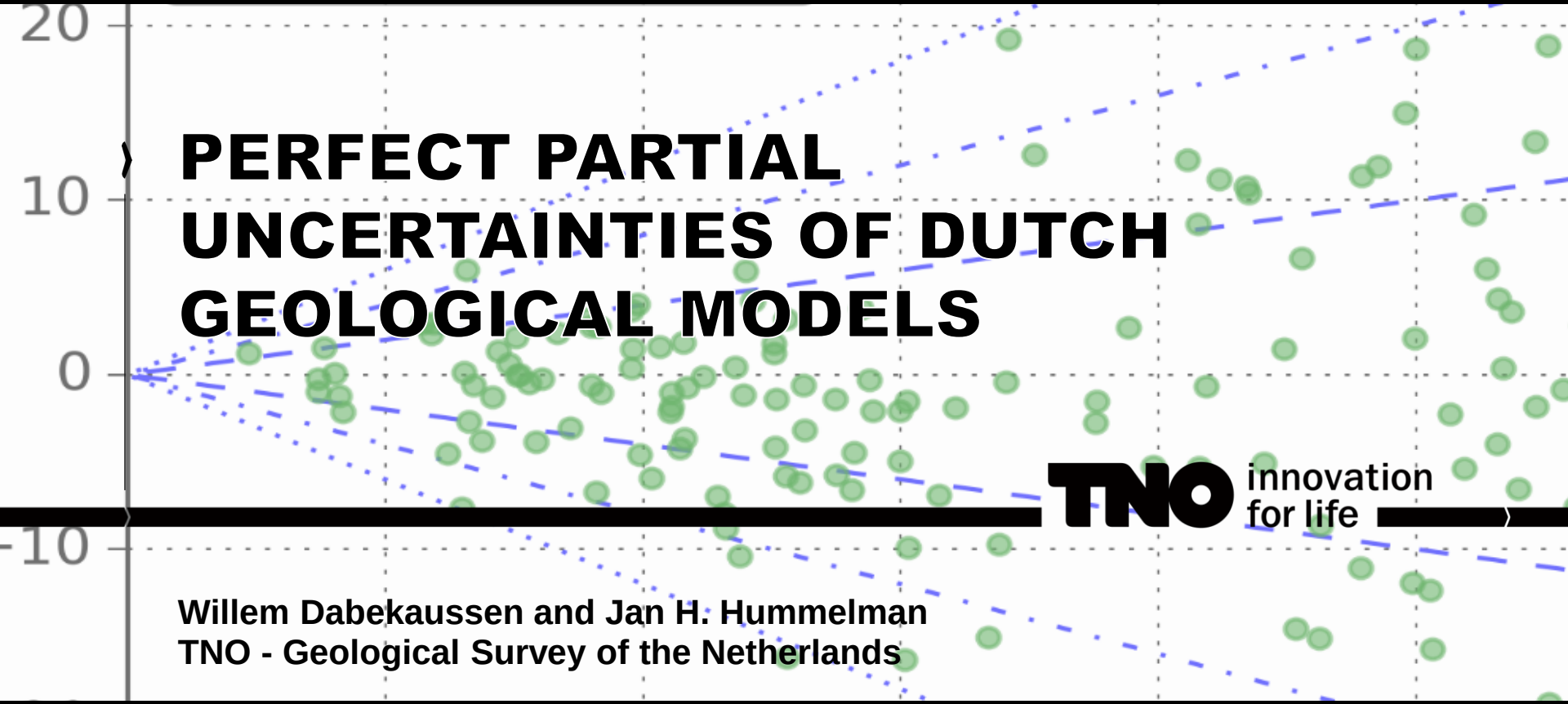


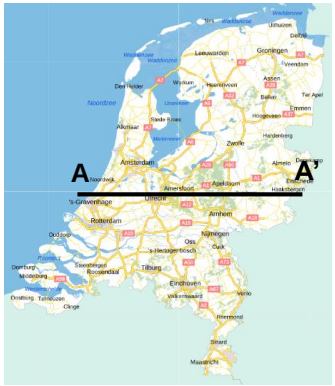
PERFECT PARTIAL UNCERTAINTIES OF DUTCH GEOLOGICAL MODELS

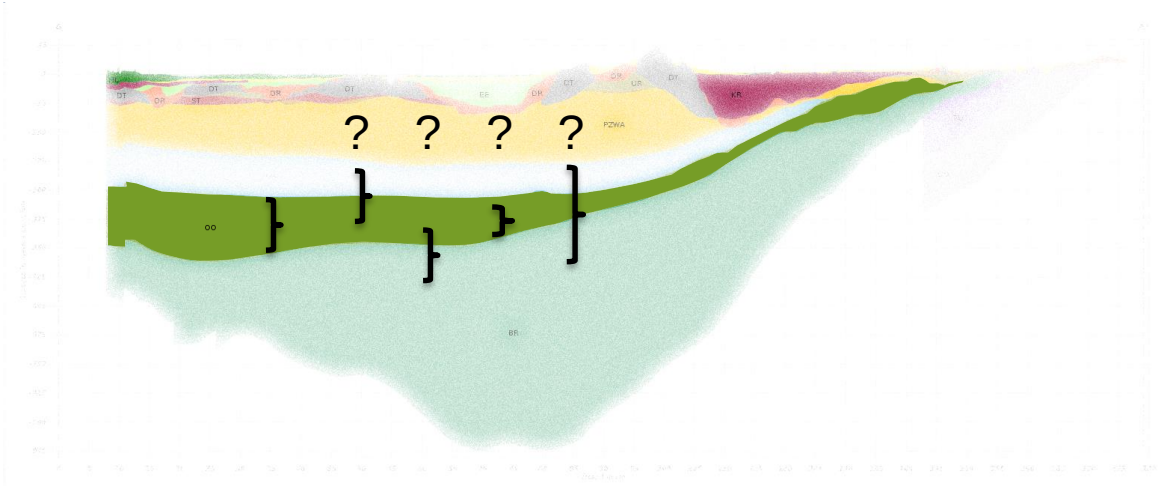
TNO innovation for life

Willem Dabekaussen and Jan H. Hummelman
TNO - Geological Survey of the Netherlands

WHY UNCERTAINTY

- Good estimation of uncertainty essential for quantitative view on model





Perfect partial uncertainties of Dutch geological models

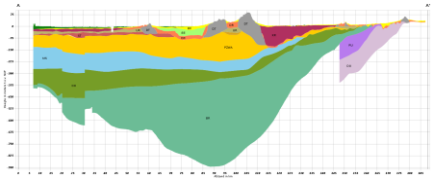
SHALLOW MODELS AT GSN

- Models at GSN up to 500m deep: based on boreholes

This presentation:

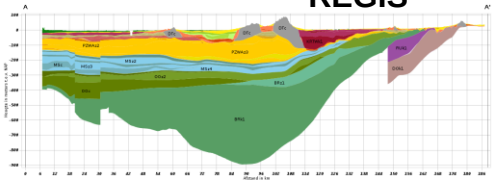
- DGM Uncertainty calculation
- DGM Uncertainty validation

DGM



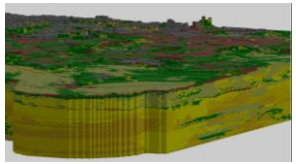
Serves as stratigraphic framework
26.000 boreholes

REGIS



Subdivision in aquifers and aquitards:
Parameters as conductivity, transmissivity etc.

GeoTOP

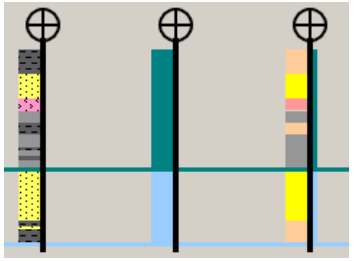


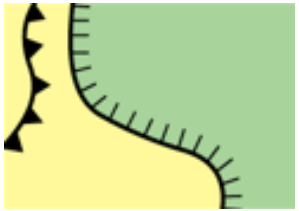
Top 50 meter voxel model
Lithology
~300.000 boreholes

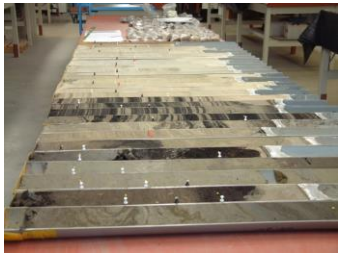
CONTRIBUTIONS TO UNCERTAINTY

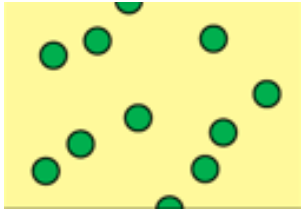
Uncertainty in stratigraphical framework models caused by:

- Borehole information:
  - Borehole location in x,y,z
  - Borehole quality
  - Sediment description
- Added geological knowledge:
  - Stratigraphic interpretation
  - Depositional extent
- Location of faults
- Aid interpolation with:
  - Trend surfaces
  - ‘Support points’
- …
- **Interpolation of point data**









CALCULATION OF UNCERTAINTY

Options:

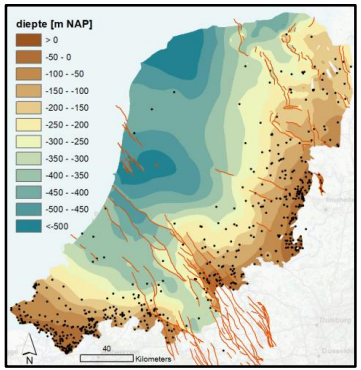
1. Kriging variance
   - Based on spatial distribution of data and variogram
   - Unrealistic uncertainty estimation in areas with low/high complexity
2. Simulations
   - Computation time
3. **Cross validation**

Steps in uncertainty calculation:

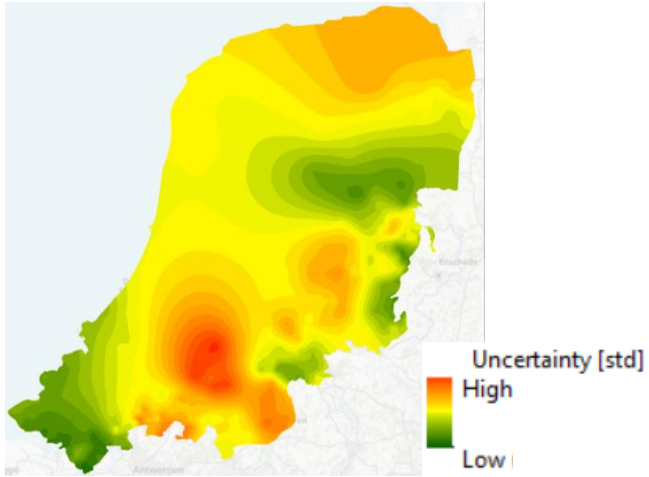
- Determine regional uncertainty
- Lower uncertainty close to data

REGIONAL UNCERTAINTY

Depth of Formation



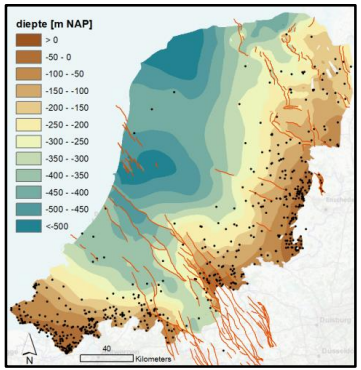
Cross validation statistics

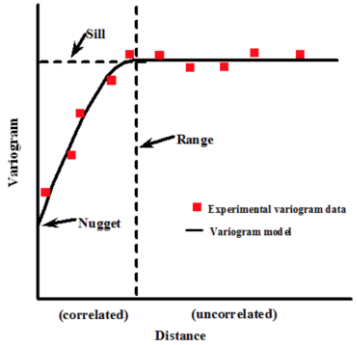


Regional uncertainty

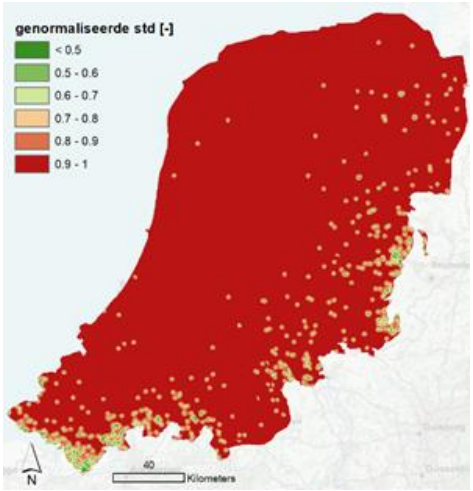
LOCAL DATA DENSITY

Depth of Formation





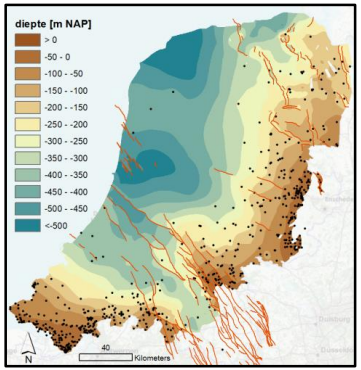
Normalised kriging variance



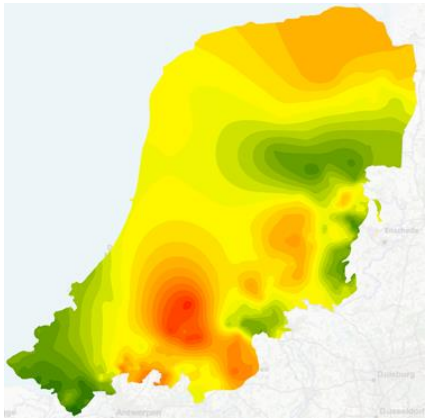
Data density

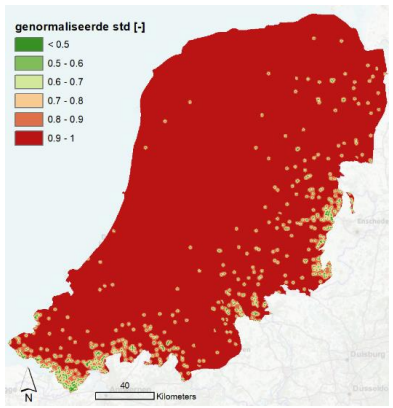
LOCAL UNCERTAINTY

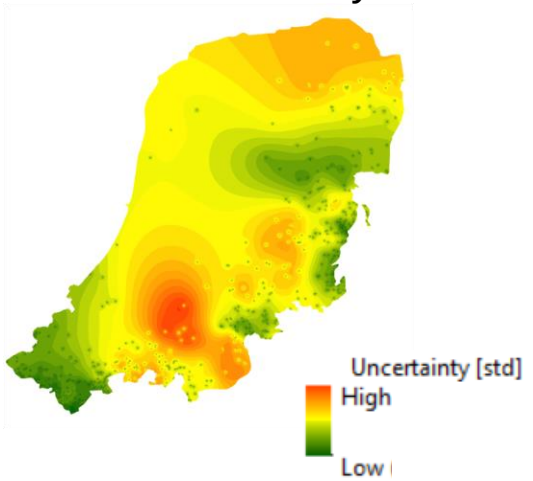
Depth of Formation



regional uncertainty * local data density = local uncertainty







Perfect partial uncertainties of Dutch geological models

CERTAINTY ABOUT UNCERTAINTY

How good is our uncertainty estimation?

- *Complete cross validation*: predict model outcome *including uncertainty* at borehole location
- Compare left out data with model
- Repeat for many data points

Prediction Residual	$PR_i = \hat{Z}_i - Z_i$
Mean Error	$ME = \frac{1}{n}\sum_{i=1}^{n}(PR_i)$
Standardized Prediction Residual	$SPR_i = PR_i/\hat{\sigma}_{loc,i}$
Proportion in probability interval	$\bar{\zeta}(PI) = \frac{1}{n}\sum_{i=1}^{n}\zeta(s_i;PI)$ with $\zeta(s_i;PI) = 1\ als\ 0 <\ \|SPR_i\| < SPR(PI)$, else 0.

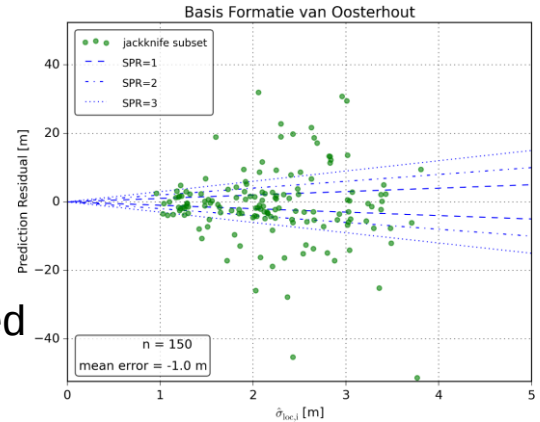
The chance of rain for that day was higher than forecast,
but not quite so high that it actually rained that day

Gummbah (2002)
Echte nachten, stugge vachten.

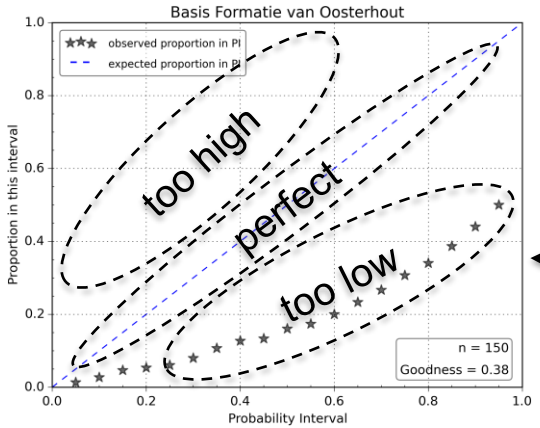
VALIDATION OF UNCERTAINTY (DGM 2014)

- Cross validation statistics reveal a large underestimation of our model uncertainty

Difference model and cross validated data



Modelled uncertainty

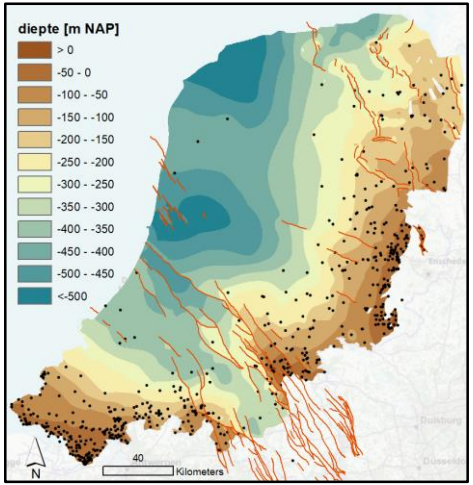


Real probability from cross validated data

Modelled probability

NEW UNCERTAINTY CALCULATIONS

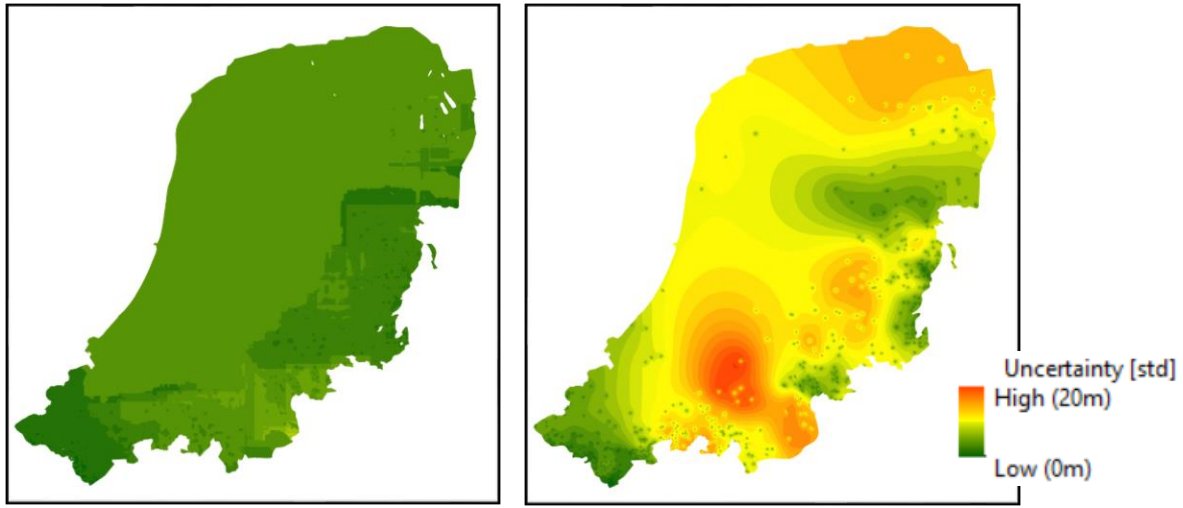
Depth of Formation base



UNCERTAINTY

DGM 2014

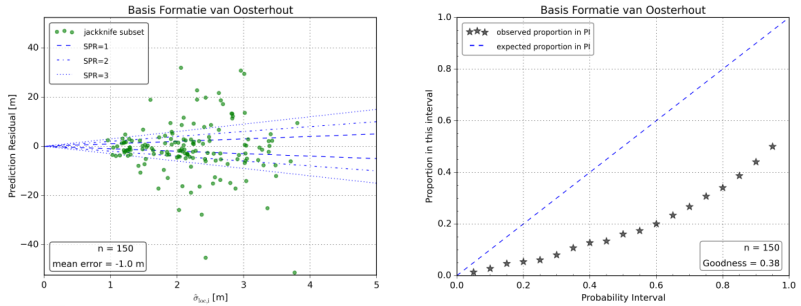
NEW



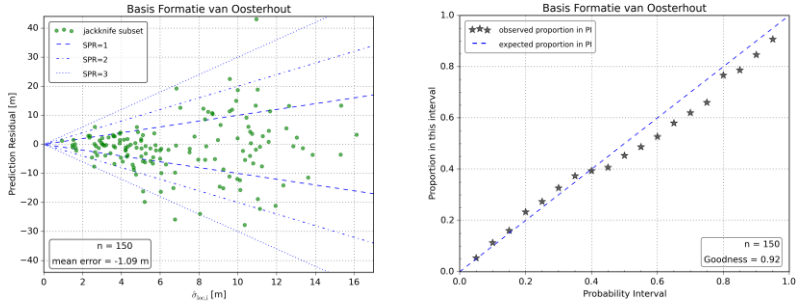
Perfect partial uncertainties of Dutch geological models

VALIDATION OF UNCERTAINTY

OLD



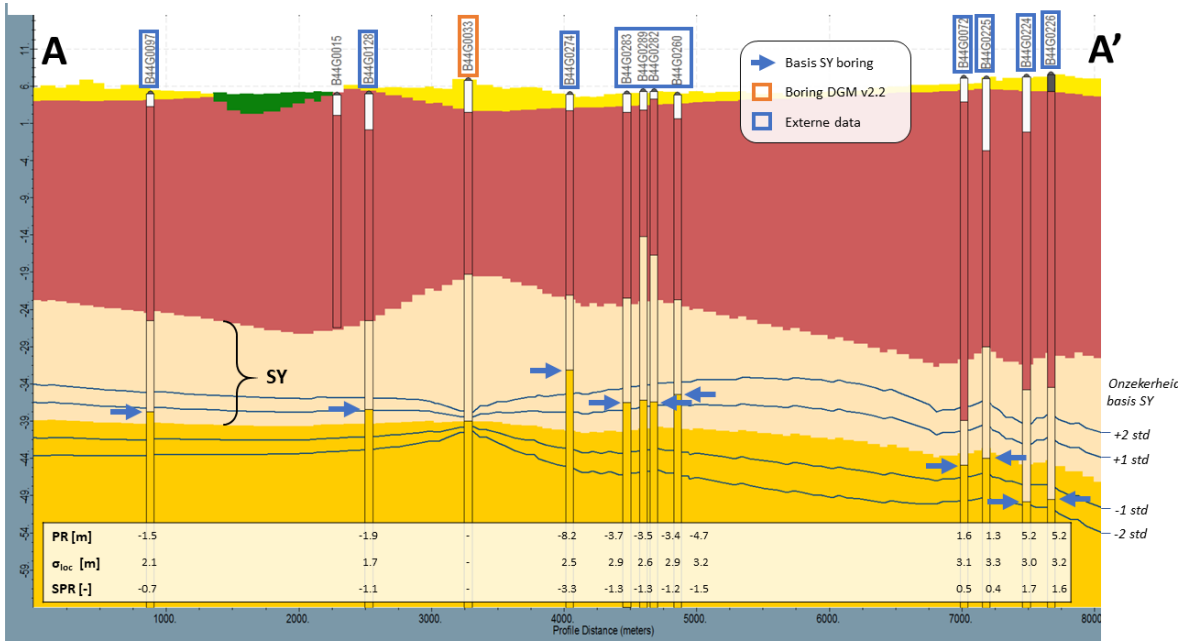
NEW

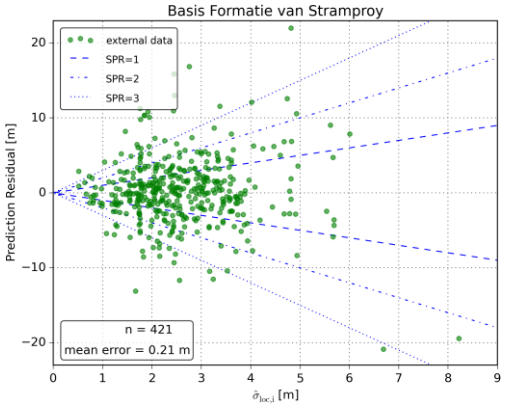


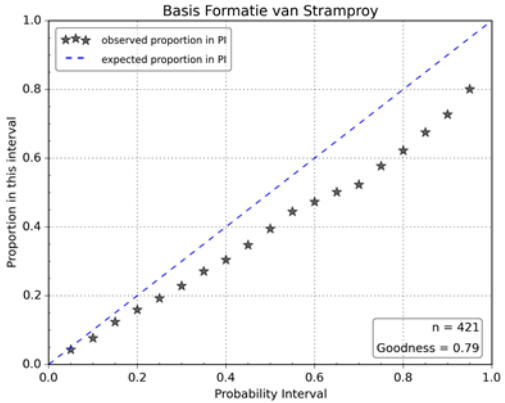
- Uncertainty 3 to 4 times higher
- Leads to almost perfect estimation of model uncertainty

Perfect partial uncertainties of Dutch geological models

DOES IT REALLY WORK?

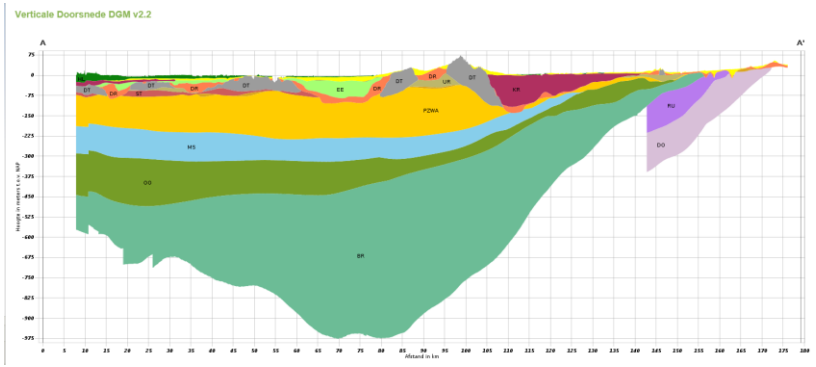






Perfect partial uncertainties of Dutch geological models

PERFECT UNCERTAINTY?



Underestimation of uncertainty in previous models has lead to… 0 user comments!

Uncertainty information easy to consult?

- Standard view does not include uncertainty

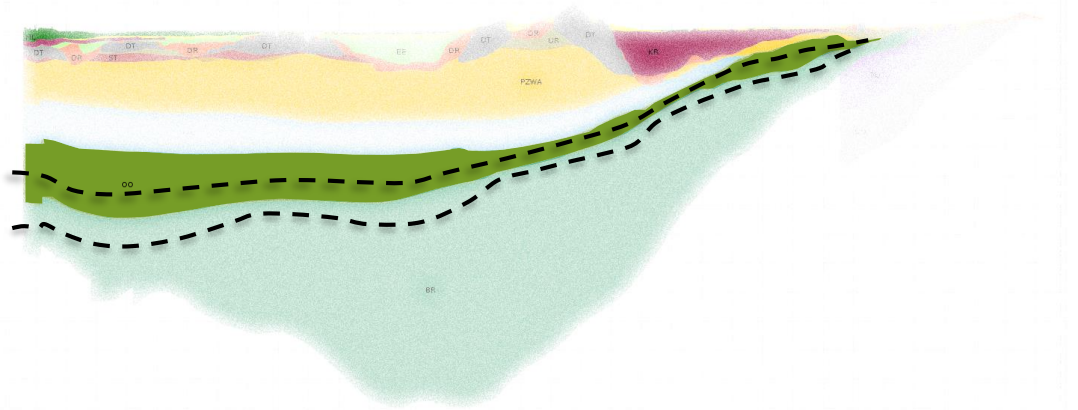
Calulated uncertainty only partial because:

- Perfect uncertainty of interpolation in geological framework models
- ‘Soft’ data treated as certain data

FUTURE?

Make uncertainty unavoidable:

- Visualisation in most standard web view



Towards a complete uncertainty:

- Include uncertainty of data
- Include uncertainty of data interpretations