Supplement of Solid Earth, 8, 515–530, 2017
http://www.solid-earth.net/8/515/2017/
doi:10.5194/se-8-515-2017-supplement

Solid Earth
Open Access

Supplement of

Uncertainty assessment in 3-D geological models of increasing complexity

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The Structural Uncertainty workflow of SKUA requires a set of parameters and input modes to be defined by the modeler.

For each fault, three different input modes were available: 1) constant symmetry, 2) move with others (MWO) and 3) fixed. A maximum displacement and probability distribution was assigned when available for the input mode. Minor faults and those indirectly constraint by surrounding faults or boreholes were set to move with others. All other faults were set to constant symmetry. Maximum displacement values are either averaged by combining multiple sources (gk1, gk4, tec3) or by an educated guess by the authors. To allow for a realistic distribution of realizations around our average estimate we chose a Gaussian distribution in all cases. A summary of all used fault parameter settings is shown in Table S1.

Table S1: Fault parameter settings used in the Structural Uncertainty Workflow of SKUA.

Fault	Input Mode	Maximum Displacement [m]	Distribution	Model
gk1	constant symmetry	45	Gaussian	1,2,3,4
gk3	MWO	NA	NA	1,2,3,4
gk4	constant symmetry	70	Gaussian	1,2,3,4
tec3	constant symmetry	10	Gaussian	1,2,3,4
KP1	MWO	NA	NA	1,2,3,4
StrnA	MWO	NA	NA	3,4
StrnE	constant symmetry	10	Gaussian	3,4
Strn1	MWO	NA	NA	4
Strn2	constant symmetry	10	Gaussian	4
Strn3	constant symmetry	5	Gaussian	4
Strn4	MWO	NA	NA	4
Strn6	constant symmetry	10	Gaussian	4
Strn7	constant symmetry	5	Gaussian	4
Strn8	constant symmetry	5	Gaussian	4

NA = not applicable; MWO = move with others

In addition to the three above mentioned input modes, a forth setting ”existing surface” is available to model the uncertainty of horizons. The existing surface input mode uses an alternative surface interpretation to constrain model realizations. We constructed alternative surface interpretations that reflect a maximum deviation in dip and azimuth of $\pm 5°$ from the original horizon surfaces. Horizons for perturbation were chosen based on the premises that a continuous representative horizon surface, build from input data during explicit modeling (Figure 4) was available across all fault blocks. For Model 4, an alternative surface interpretation was possible only for unit ku, because the domain was strongly fragmented after adding the seismic data; and no other unit could be represented continuously across all fault blocks. Furthermore, perturbations applied to an initial surface were spatially cor-

Table S2: Variogram parameter settings used in the Structural Uncertainty Workflow of SKUA.

Variable	Value	Value	Variable
R1 (max)	1000 m	Azimuth	305 °
R2 (max)	1000 m	Dip	140 °
R3 (vertical)	200 m	Plunge	0 °

related using a variogram with the same parameter values for all four models (Table S2).

Maximum displacement was determined based on the unit thickness information (Figure 3) and constraints from wells. The applied settings reflect an overall possible displacement of 30 m across all horizons, while avoiding unrealistic thickness perturbations of the relatively narrow ku unit by applying constraints on its upper and lower boundary surfaces (MWO or existing surface). All horizon parameter settings are summarized in Table S3.

Table S3: Horizon parameter settings used in the Structural Uncertainty Workflow of SKUA.

Unit	Input Mode	Maximum Displacement [m]	Honor Well	Model
DTM	fixed	NA	NA	1,2,3,4
j	MWO	NA	Yes	1,2,3,4
km3	constant symmetry	30	NA	1,2,3,4
km2	existing surface	surface	Yes	1
km2	MWO	NA	Yes	2,3,4
km1	existing surface	surface	Yes	1,2,3
km1	MWO	NA	Yes	4
ku	constant symmetry	30	Na	1
ku	existing surface	surface	Yes	2,3,4
mo	MWO	NA	NA	1,2
mo	MWO	NA	Yes	3,4
mm.mu	constant symmetry	30	NA	1,2,3,4
so	constant symmetry	30	NA	1,2,3,4
base	constant symmetry	30	NA	1,2,3,4

NA = not applicable; MWO = move with others