New Features in PowerWorld Simulator GIC Version 20

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Summary

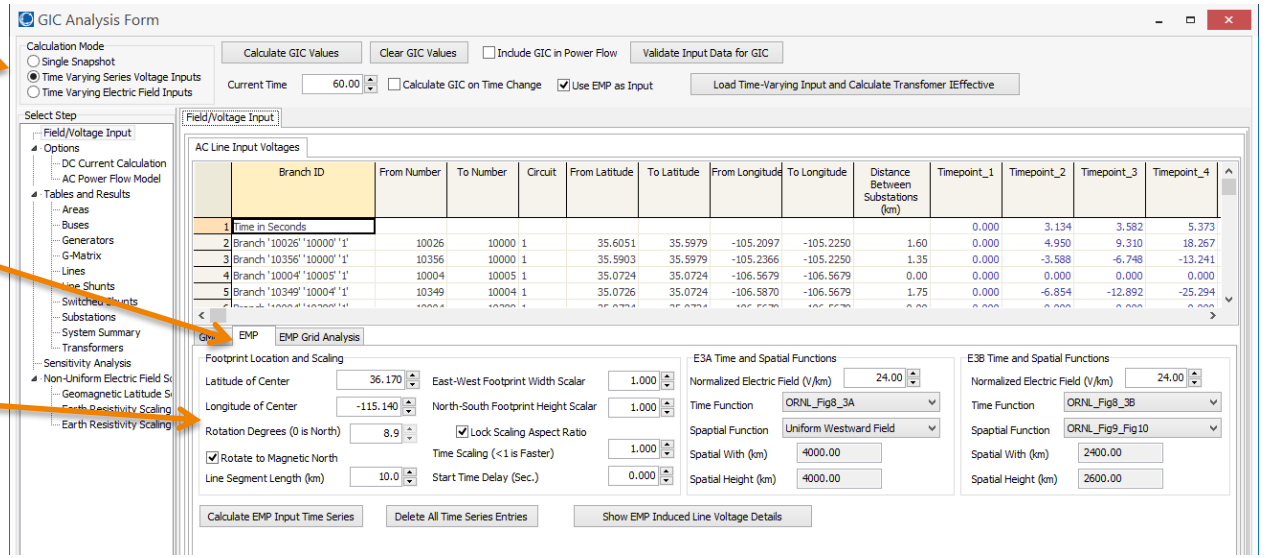
- High-Altitude Electromagnetic Pulse (HEMP or EMP) modeling
  - The late-time (E3) effects of a nuclear detonation tens of km over the surface of the Earth gives rise to geomagnetic disturbances (GMD) similar to a coronal mass ejection from the sun
  - EMP or time-varying GMD simulation in Transient Stability
- NERC Benchmark Event Time Series

EMP Modeling

- EMP disturbances have faster rise times than solar GMD, but may last only several minutes
- It often makes sense to analyze EMP in the transient stability domain
  - Incorporate load shedding, generator exciters, excitation limiters, and other characteristics not modeled in power flow

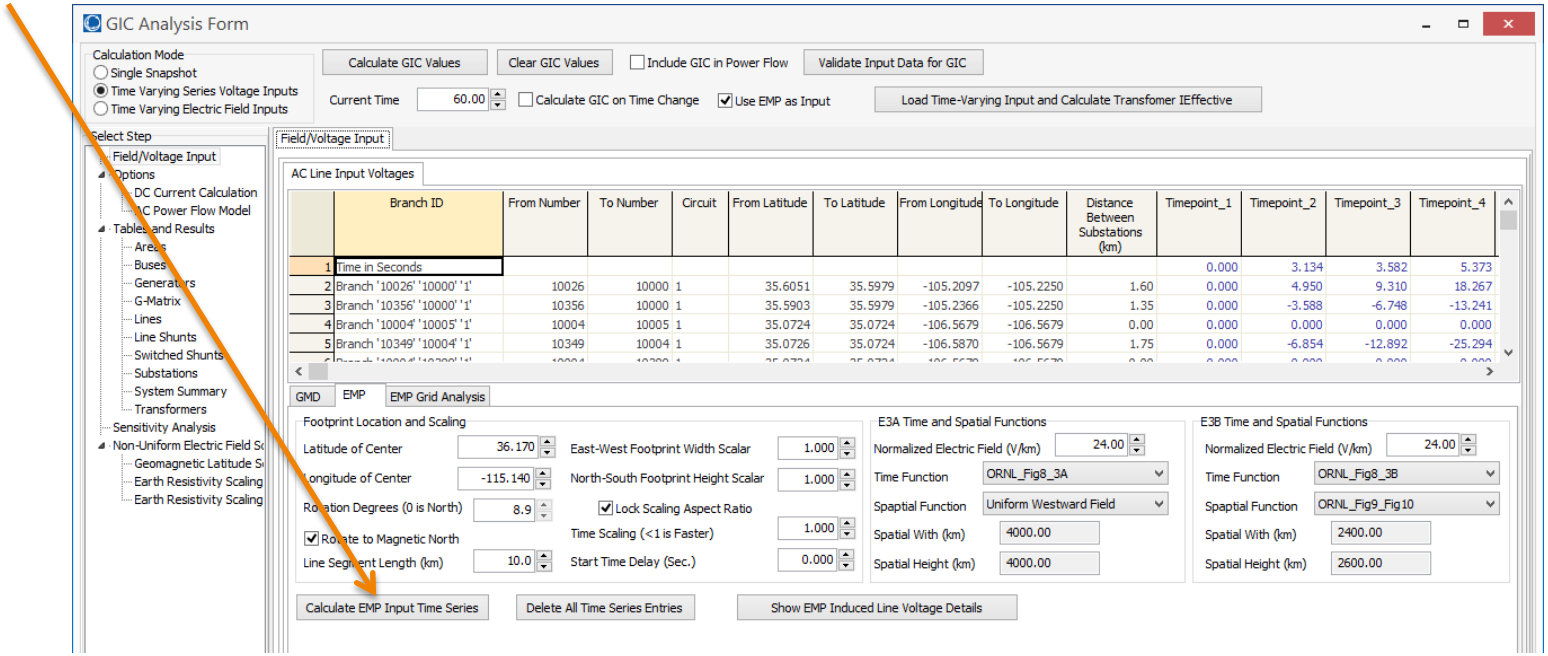
EMP Time and Spatial Functions

- From GIC Analysis Form, choose **Time Varying Series Voltage Inputs** Calculation Mode
- On the **Field/Voltage Input** page, choose **EMP** tab
- Enter parameters for **Footprint Location and Scaling**
- Enter **E3A** and **E3B Time and Spatial Functions** (choices from Oak Ridge National Lab paper and IEC 61000 2-9 standard)



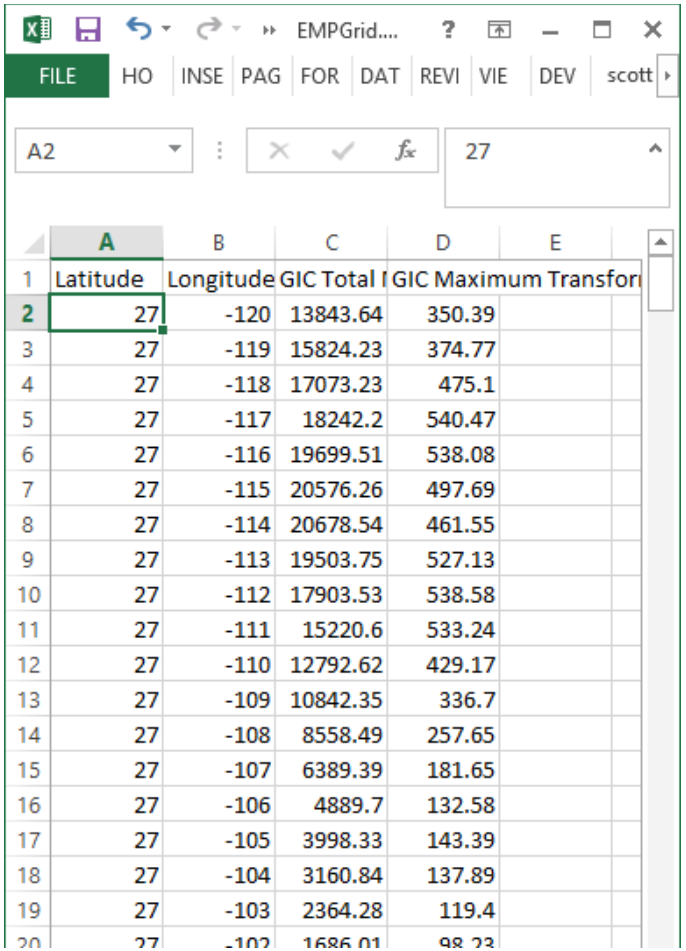
EMP Time and Spatial Functions

- Click “Calculate EMP Input Time Series” button for corresponding equivalent DC voltages in each transmission line



EMP Grid Analysis

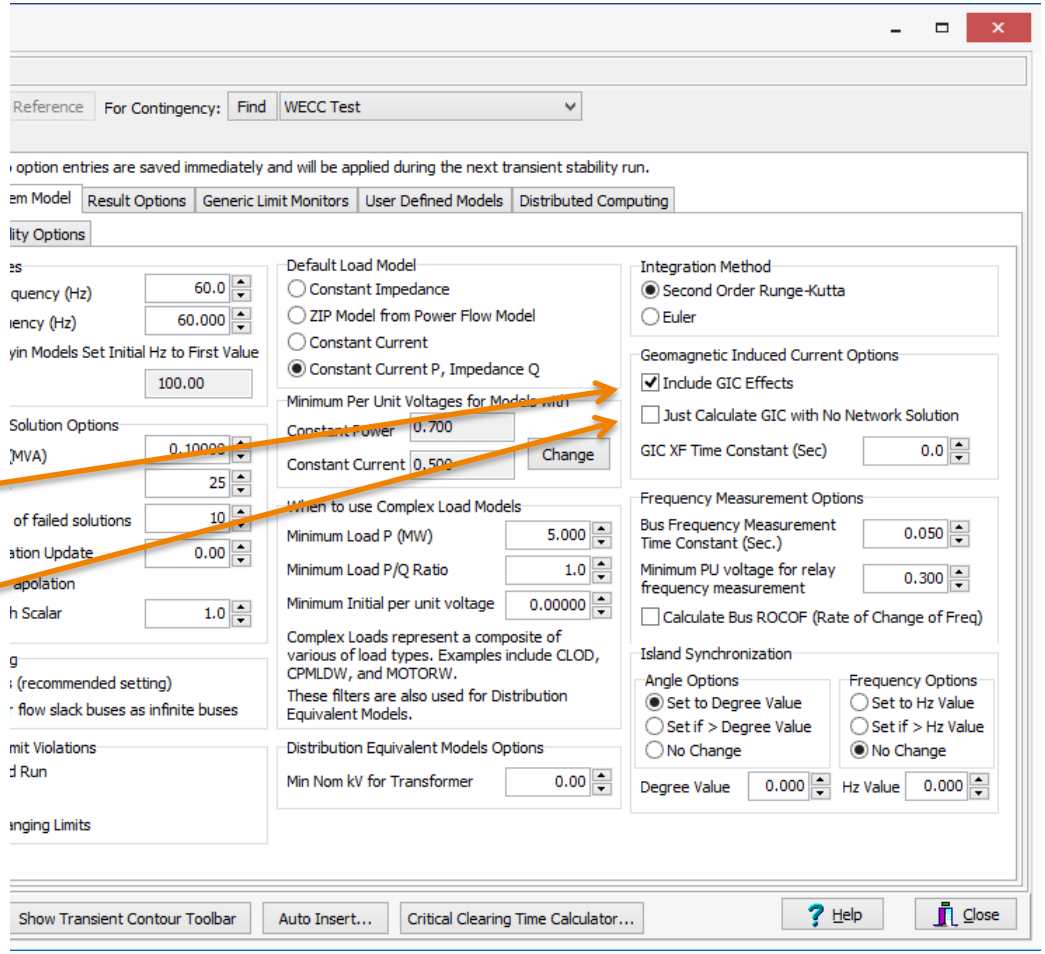
- Creates a csv file with system Mvar losses and highest single transformer Effective GIC for each location in a grid defined by start and end latitude and longitude, and degree increment
- Fast method of screening for possible worst-case EMP center locations
- Does not include AC power flow solution or transient stability analysis (only summary results from DC GIC flows)



	A	B	C	D	E
1	Latitude	Longitude	GIC Total I	GIC Maximum Transfor	
2	27	-120	13843.64	350.39	
3	27	-119	15824.23	374.77	
4	27	-118	17073.23	475.1	
5	27	-117	18242.2	540.47	
6	27	-116	19699.51	538.08	
7	27	-115	20576.26	497.69	
8	27	-114	20678.54	461.55	
9	27	-113	19503.75	527.13	
10	27	-112	17903.53	538.58	
11	27	-111	15220.6	533.24	
12	27	-110	12792.62	429.17	
13	27	-109	10842.35	336.7	
14	27	-108	8558.49	257.65	
15	27	-107	6389.39	181.65	
16	27	-106	4889.7	132.58	
17	27	-105	3998.33	143.39	
18	27	-104	3160.84	137.89	
19	27	-103	2364.28	119.4	
20	27	-102	1686.01	98.23	

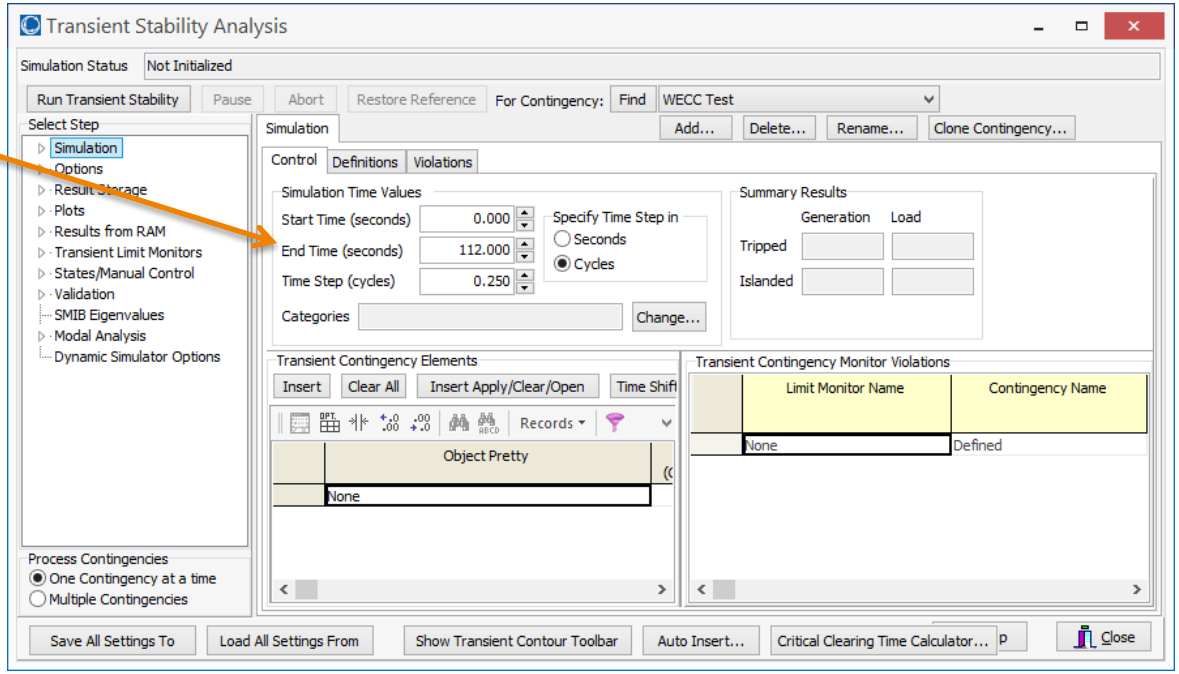
GIC in Transient Stability

- For use with Time Varying Series Voltage Inputs (GMD or EMP)
- **Options → Power System Model → Common**
- Check “Include GIC Effects”
- Optionally “Just Calculate GIC with No Network Solution” (for fast computation of GIC quantities)



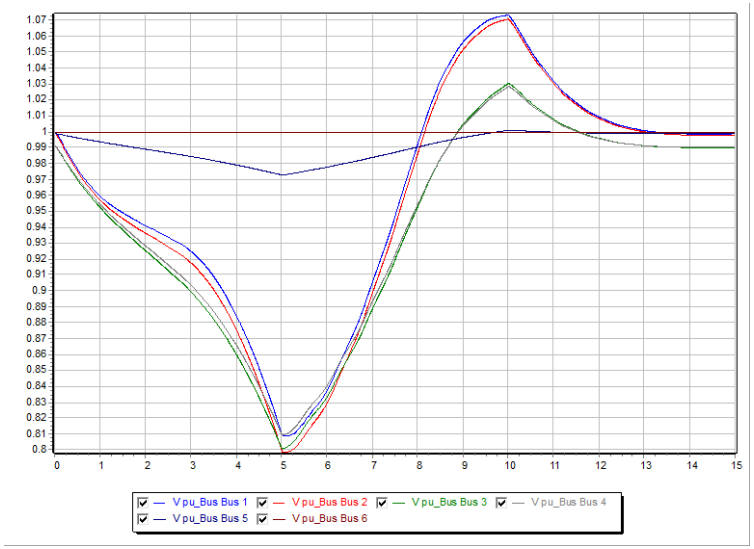
GIC in Transient Stability

- Can run with no other contingency events to simulate just the GMD/EMP
- Set Start and End Time to correspond with GIC time series

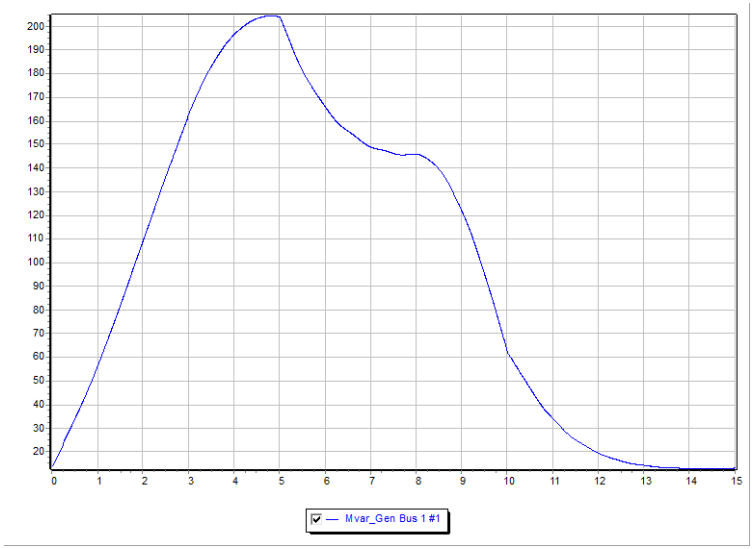


Transient Stability Example
(6-bus System)

- Bus Voltages



- Generator MVar



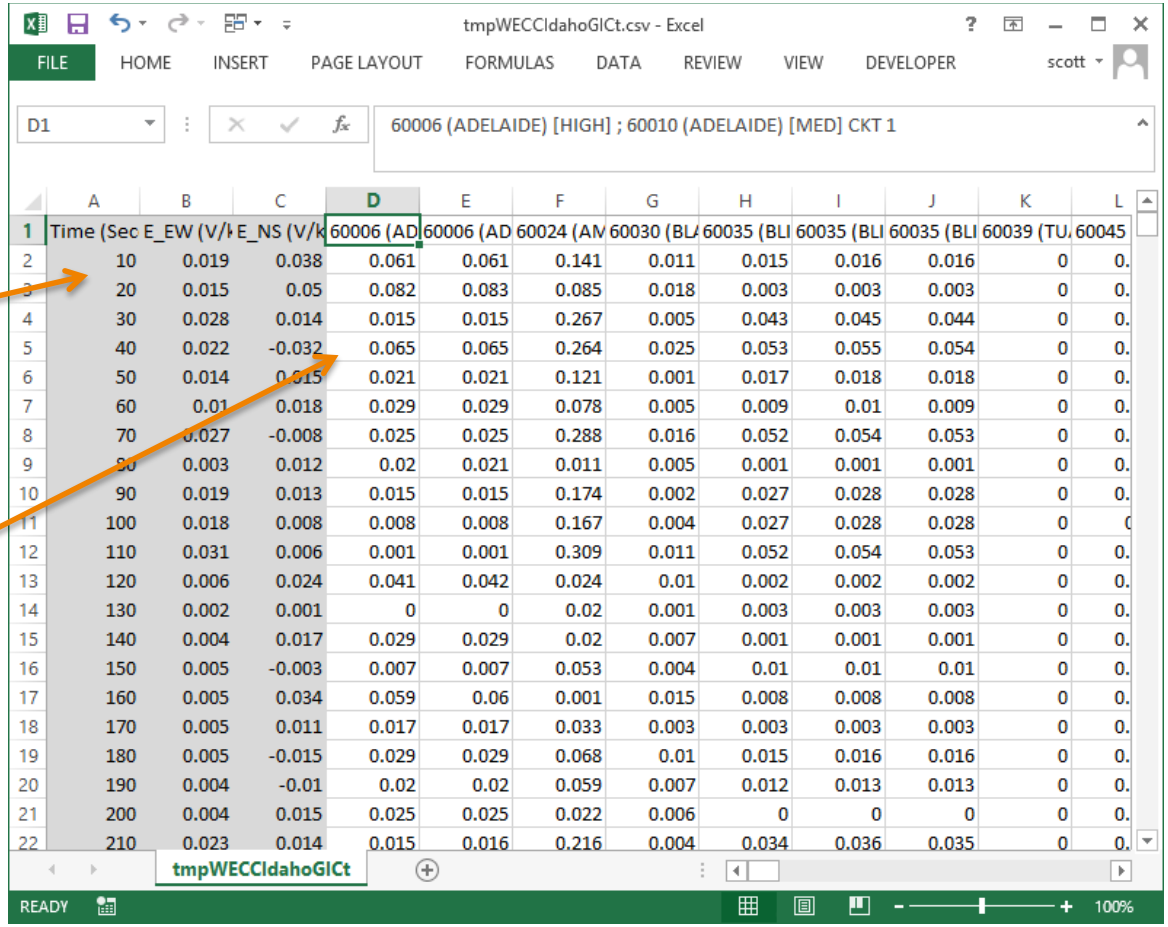
- Simulation in power flow leads to collapse at t=4.2 due to static generator Var limits
- Increasing peak field strength beyond 20 V/km leads to collapse in transient stability simulation

NERC Benchmark Event Time Series

- On GIC Analysis Form, click “Load Time-Varying Input and Calculate Transformer IEffective”
- Input in CSV format (time, northward E-field, eastward E-field)
- Output in CSV format (Effective GIC for all transformers on the GIC Transformer Display – use filter to limit size of output)

NERC Benchmark Event Time Series

- Sample output file shown
- Input time series
- Transformer GIC(t)



	A	B	C	D	E	F	G	H	I	J	K	L
1	Time (Sec	E_EW (V/k	E_NS (V/k	60006 (AD	60006 (AD	60024 (AM	60030 (BL/	60035 (BLI	60035 (BLI	60035 (BLI	60039 (TU/	60045
2	10	0.019	0.038	0.061	0.061	0.141	0.011	0.015	0.016	0.016	0	0.
3	20	0.015	0.05	0.082	0.083	0.085	0.018	0.003	0.003	0.003	0	0.
4	30	0.028	0.014	0.015	0.015	0.267	0.005	0.043	0.045	0.044	0	0.
5	40	0.022	-0.032	0.065	0.065	0.264	0.025	0.053	0.055	0.054	0	0.
6	50	0.014	0.015	0.021	0.021	0.121	0.001	0.017	0.018	0.018	0	0.
7	60	0.01	0.018	0.029	0.029	0.078	0.005	0.009	0.01	0.009	0	0.
8	70	0.027	-0.008	0.025	0.025	0.288	0.016	0.052	0.054	0.053	0	0.
9	80	0.003	0.012	0.02	0.021	0.011	0.005	0.001	0.001	0.001	0	0.
10	90	0.019	0.013	0.015	0.015	0.174	0.002	0.027	0.028	0.028	0	0.
11	100	0.018	0.008	0.008	0.008	0.167	0.004	0.027	0.028	0.028	0	0
12	110	0.031	0.006	0.001	0.001	0.309	0.011	0.052	0.054	0.053	0	0.
13	120	0.006	0.024	0.041	0.042	0.024	0.01	0.002	0.002	0.002	0	0.
14	130	0.002	0.001	0	0	0.02	0.001	0.003	0.003	0.003	0	0.
15	140	0.004	0.017	0.029	0.029	0.02	0.007	0.001	0.001	0.001	0	0.
16	150	0.005	-0.003	0.007	0.007	0.053	0.004	0.01	0.01	0.01	0	0.
17	160	0.005	0.034	0.059	0.06	0.001	0.015	0.008	0.008	0.008	0	0.
18	170	0.005	0.011	0.017	0.017	0.033	0.003	0.003	0.003	0.003	0	0.
19	180	0.005	-0.015	0.029	0.029	0.068	0.01	0.015	0.016	0.016	0	0.
20	190	0.004	-0.01	0.02	0.02	0.059	0.007	0.012	0.013	0.013	0	0.
21	200	0.004	0.015	0.025	0.025	0.022	0.006	0	0	0	0	0.
22	210	0.023	0.014	0.015	0.016	0.216	0.004	0.034	0.036	0.035	0	0.