HPC Workflow Management in Seismology: Global CMT 3D Inversion

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The centroid moment tensors (CMTs) provided by the Global CMT Project (https://www.globalcmt.org) have been a staple of global tomography for more than 40 years. With ever-advancing tomographic methodology and computational resources, more detail in Earth's interior structure is rapidly being revealed. Over the last few years, both tomography and moment-tensor inversions have shown that in a fully three-dimensional forward-modeling regime, the classic Global-CMT solutions are on average 3 km too deep, the centroid time about 1 s late, and the seismic moment approximately 5% too low. Therefore, to keep pace with the increased capacity and demands of global tomography, a new catalog of improved, global CMT solutions suggests itself as the next step. We present an application of the workflow manager EnTK, which is developed by the Radical Group at Rutgers University, to the three-dimensional CMT inversion. In combination with our developed CMT 3D inversion workflow based on the Python packages `pycmt3d` and `GCMT3D`, it provides a robust and scalable solution to the computationally intense, routine problem. In an ensemble-based fashion, the automated workflow takes Global-CMT solutions and routinely inverts for new, improved CMT solutions. The workflow includes four main steps: [1] launching of the forward, three-dimensional (3D) spectral-element-method (SEM) simulations to generate synthetics, [2] downloading of the observed seismic data, [3] processing of synthetic and observed data, and [4] inversion for the six moment-tensor parameters and the centroid latitude, longitude and depth, as well as a grid search for moment magnitude and centroid time. The computational cost of the 3D forward simulations is high; making our workflow ensemble-based ensures its simplicity and scalability, both critical factors for the recomputation of the thousands of Global-CMT solutions that already exist today. Finally, the CMT inversion results will be integrated into the existing workflow for routine computation of global earthquake synthetics, made available by the ShakeMovie website (http://global.shakemovie.princeton.edu) which provides seismologists with a simple interface to access the new CMT solutions as a complement to the original ones. An example output of a CMT inversion can be seen in the attached figure.

200709121110A

Init CMT

Mw=8.551

lat=-3.780 °; lon=100.990 °

dep=24.420 km;

Station Dist and Azi

315°   45°

270°   90°

225°   135°

180°

Station Azimuth

315°   45°

270°   90°

225°   135°

180°

Window Azimuth

315°   45°

270°   90°

225°   135°

180°

Number of stations: 289   Number of widnows: 645 Envelope coef: %5.2f
Number of Parameter: 9   Zero-Trace: True   Double-couple: False
Station Correction: True   Norm_by_energy: False   Norm_by_category: False
Inversion Damping: 0.000   Energy Change: -2.50%   Variance Reduction: 6.71%
******************** Summary Table   ====================

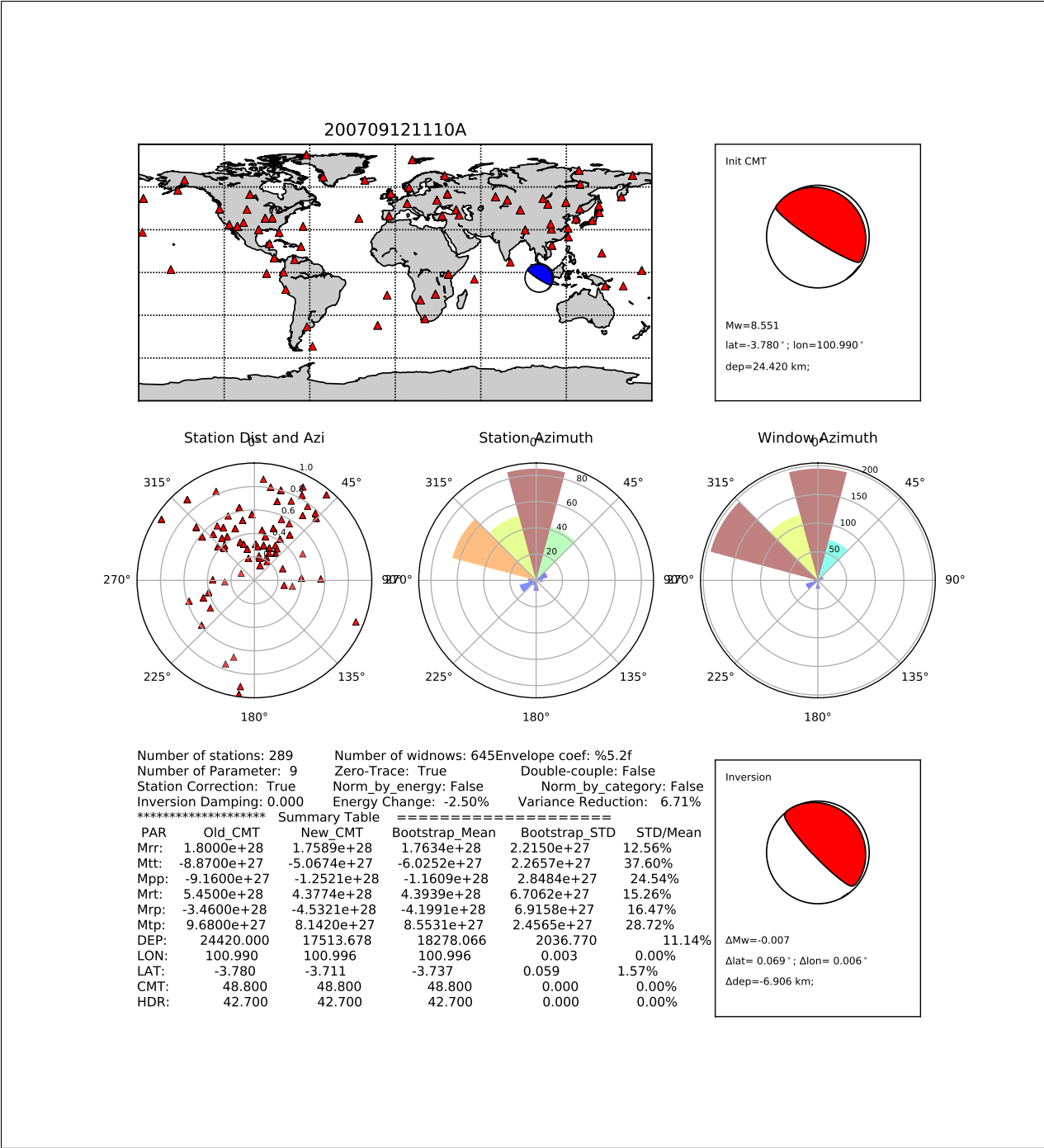| PAR	Old_CMT	New_CMT	Bootstrap_Mean	Bootstrap_STD	STD/Mean
Mrr:	1.8000e+28	1.7589e+28	1.7634e+28	2.2150e+27	12.56%
Mtt:	-8.8700e+27	-5.0674e+27	-6.0252e+27	2.2657e+27	37.60%
Mpp:	-9.1600e+27	-1.2521e+28	-1.1609e+28	2.8484e+27	24.54%
Mrt:	5.4500e+28	4.3774e+28	4.3939e+28	6.7062e+27	15.26%
Mrp:	-3.4600e+28	-4.5321e+28	-4.1991e+28	6.9158e+27	16.47%
Mtp:	9.6800e+27	8.1420e+27	8.5531e+27	2.4565e+27	28.72%
DEP:	24420.000	17513.678	18278.066	2036.770	11.14%
LON:	100.990	100.996	100.996	0.003	0.00%
LAT:	-3.780	-3.711	-3.737	0.059	1.57%
CMT:	48.800	48.800	48.800	0.000	0.00%
HDR:	42.700	42.700	42.700	0.000	0.00%

Inversion

ΔMw=-0.007

Δlat= 0.069 °; Δlon= 0.006 °

Δdep=-6.906 km;

Figure 1: Preliminary example inversion output