Southern California Earthquake Center Community Geodetic Model Workshop

Saturday, September 7, 2019, 09:00–17:00 PDT; Hilton Palm Springs, California

Workshop Report

https://www.scec.org/workshops/2019/cgm

Conveners

Michael Floyd (Massachusetts Institute of Technology)
Gareth Funning (University of California, Riverside)
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David Bekaert (Jet Propulsion Laboratory)
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Summary

The Community Geodetic Model (CGM) workshop held before the 2019 SCEC Annual Meeting attracted over 30 participants, including a large number of actual or potential product users, who engaged in a lively and constructive debate about the current status and immediate future of the CGM. The feedback from users was particularly useful as this had been a largely neglected component of input in the past. New ideas were expressed particularly regarding the issue of product availability of useability, including for students being taught in courses. A clear set of recommendations from users was determined, including being able to understand the basic construction of the products, use them confidently and cite them accordingly in peer-reviewed work.

We will endeavor to hold bi-monthly telecons for the whole CGM Working Group in the future, as well as bi-monthly telecons in the intervening months separately for the main focus groups (GNSS and InSAR) to continue to address the issues raised and discussed during the workshop.

Session 1: Current status of CGM products and research

The first session was dedicated to updating the whole working group, which included several first-time attendees, on the current status of the CGM products and web site (https://www.scec.org/research/cgm). The CGM web site has been hosted at SCEC since early summer 2019 but has yet to be updated to complete current descriptions of research priorities, groups and accomplishments, data products, and contributors. The current basis of most of this information is the technical report on the CGM version 1 horizontal velocity grids (https://topex.ucsd.edu/CGM/technical_report/CGM_V1.pdf).

Mike Floyd (MIT) introduced the workshop by presenting some basic information on the structure and relationship of various different components of the CGM, and specifically showed the details of how the continuous GNSS time series are currently sourced, combined and fit. One pressing point mentioned was AGU journals' recent change to publishing policy, which essentially requires any data presented to be made available through a community repository. This compels the need for the CGM to address the issue of data and product citation as soon as products are made available

for the community to use, potentially in publications. The GNSS working group, at least, addressed this issue in their breakout group discussion, described below in Session 2.

Three short presentations were given by CGM contributors best suited to summarize the three main components of the CGM: Tom Herring (MIT) on the state of the continuous GNSS products; Zheng-Kang Shen (UCLA) on the state of survey GNSS products; and David Bekaert (JPL) demonstrating the ARIA project's InSAR products, upon which the CGM could rely or build for our own products. The Herring and Bekaert presentations are available at https://www.scec.org/workshops/2019/cgm.

Session 2: Next Steps for Version 2 of a Time-Independent CGM

In the second session, the workshop participants split into three breakout groups: one of GNSS experts, one of InSAR experts and one of potential users and other interested parties. At previous workshops we had split into groups where each breakout group was intentionally mixed to aid understanding between technical producers and specific users but, given the need for clear action items to move the CGM products forward, we decided here to have specific-interest groups.

The GNSS group focused on the priority of ensuring source analyses are maintained and the justification for the CGM GNSS products, namely that regional operational processing centers may change strategies or access, as Tom Herring pointed out in his presentation in Session 1, but the combination strategy of the CGM should mitigate any dropouts. Throughout the workshop, from technical experts and users alike, the issue of rigorous and consistent reference frames was raised. We therefore concluded that pressing the analysis centers whose products are ingested and combined to create the CGM products to make available their transformation files (e.g. "x"-files from GIPSY) would be helpful to the CGM efforts, as such intermediate files are likely generated during analysis anyway. In a similar fashion, we suggested that, during time series analysis to estimate velocities and their associated uncertainties, that more technical results such temporal correlation statistics and outlier estimates for advanced users. Finally, the GNSS breakout group proposed writing a data-focused paper, such as in AGU's Earth and Space Science, to provide details of the construction of the CGM, which can then be cited by users of the CGM products. The push for citable data and products sources is one that UNAVCO and publications already provide.

The InSAR group focused on a singular goal, namely to produce a first InSAR-based geodetic velocity solution and, where possible, time series. This may then be offered as a CGM product, in parallel or in combination with the equivalent GNSS products. PI Floyd asked the InSAR group to develop a "road map" for how this would be achieved in the next year. The conclusion was to select a test data set and covering southern California and task each active institution in the Working Group (e.g. SIO, JPL) to generate time series, a velocity field and uncertainties by their chosen method. Subsequent comparison and combination of these products will guide future research topics but the basis must be a "Version 1.0" InSAR product. The group noted how important the ARIA project is to these goals, and the CGM as a whole, as a source of data, processing and expertise, and SCEC and the CGM should therefore strongly emphasize the community interest in the ARIA project in future Science Plans and

Requests For Proposals to support its continuation towards SCEC goals. The InSAR group raised a series of questions for future research to address, which are provided under *Action Items*, below.

The users group discussed individual and mutual needs, and provided a detailed list of, which was then reduced to a few specific recommendations for CGM products and accessibility options to be provided as soon as possible. Ultimately, the advice of the users, as it has in the past, means treading the thin line between being informative but concise versus too technical or inaccessible to those with more basic knowledge. Fundamentally, the solution suggested for this quandary is simply to provide meaningful documentation of the products and garner feedback to iterate from there.

Session 3: Geodetic Response to the July 2019 Ridgecrest events and impact on the CGM

The influence of large earthquakes on the CGM was discussed by the whole group in Session 3. Graduate student Zach Young (UNR) presented the observations and initial results from the Nevada Geodetic Lab and Chris Milliner (JPL) presented recent work on optical image observations of the earthquakes to generate discussion on whether such products should be included in the CGM in addition to GNSS and InSAR. We concluded that, while very useful, optical imagery tends not to be used for long-term, low-rate studies, such as is the basis for the CGM products. Likewise, it was broadly agreed that it should not be within the CGM's scope to organize event responses or provide processing services specifically associated with any earthquakes. The availability of response.scec.org, whose existence was reiterated during the workshop, was deemed to be sufficient for the purposes of geodetic earthquake response.

However, given the knowledge and experience of the CGM Working Group, we did agree that updating the KML file compiled by Duncan Agnew for the previous Crustal Motion Model (CMM; Shen et al., 2007) would be very helpful to those wishing to know which sites have been measured, and when, in the event of earthquake response. This information may also be provided by, as stated under *Session 2*, having readily available time series products whose number of records and last data point can be used to understand targets for both updates of interseismic observations and those most likely to produce scientifically useful results quickly in the aftermath of a large event.

Session 4: Future Steps Towards a Time-Dependent CGM

Ultimately, the workshop's goal was to generate a clear set of tasks to (a) fulfill as-yet incomplete goals (e.g. according to the SCEC Science Plan for the CXMs), (b) to organize action items to fulfill upcoming tasks in the Science Plan and (c) ensure that any feedback we have received in the interim is considered and used to guide these next steps based on changing ideas of what the community wants and needs.

The session was based on general discussion and we consider the following action items to be the most generally important at this time.

Action Items (e.g. ideas for proposals)

1. GNSS

- Update programs and combination workflow to accommodate recent changes in many of the analysis centers' products upon which the CGM GNSS products rely (this will likely require direct contact with the analysis centers to ensure continuity of required products and metadata)
- Rigorously combine Zheng-Kang Shen's survey time series with the continuous time series generated by Tom Herring and Mike Floyd at MIT, in a consistent and well-documented format (".pos" format; https://www.unavco.org/data/gps-gnss/derived-products/docs/NOTICE-TO-DATA-PRODUCT-USERS-GPS-2013-03-15.pdf)
- Start to include spectral (or, at least, meaningful temporal noise characteristic) information on the time series fits when estimating velocity; these secondary products are still interesting to some researchers
- Lead an effort to produce a paper in a peer-reviewed journal (e.g. Earth and Space Science) based on the construction of at least the GNSS side of the CGM to summarize and advertize, much like Herring et al. (2016) in Review of Geophysics, which serves as the de facto reference for the GAGE products.

2. InSAR

- Establish a clear and explicit "roadmap" and workflow for the CGM InSAR products, similar to what has already been done for the GNSS component:
    - Agree on a test data set, including acquisition dates, reference points and tracks
    - Separate groups produce time series and (line-of-sight) velocities and associated uncertainties based on their preferred processing strategy
    - Compare the various results and combine them in a systematic way to generate the final "CGM" product
- Reach consensus on integration of different satellite systems into a single, consistent and rigorously-defined CGM InSAR products and, ultimately, the combination with the GNSS component
- Consider the guidance provided by long-standing GNSS practices and current CGM user requirements when applying corrections (e.g. surface loading), estimating uncertainties (particularly with temporal correlations) and defining and removing terms such as seasonal and transient motions when fitting time series
- Guide and assist Working Group on development of Jupyter notebooks based on what has already been done for and in collaboration with UNAVCO

3. Users

- Engage in any feedback surveys to provide more continuous support and guidance for products that are being generated already
- Similarly assist with iteration of documentation, as requested by many users, as it is written and associated with CGM products

- Guide and assist Working Group on development of Jupyter notebooks for user interaction (and teaching)

4. CGM Working Group

- Complete the transfer of CGM version 1 products to https://www.scec.org/research/cgm from web pages hosted by David Sandwell (https://topex.ucsd.edu/CGM/), Zheng-Kang Shen (http://scec.ess.ucla.edu/~zshen/cgm/) and Mike Floyd (http://geoweb.mit.edu/~floyd/scec/cgm/).
- Prepare to create digital object identifiers (DOIs), so that any CGM products may be cited appropriately, and consider how to make a dynamic update scheme for this as new products are added, e.g. continuous GNSS time series extension.
- Look to build user interface which provides the main products and basic search criteria that users say they want, e.g.
    - Temporal and spatial search facilities; possibly simple KML files for some basic information
    - Tutorials on data access, provenance and extraction
- Advertise more formally the two main advantages of the CGM, i.e. combination of multiple analysis centers for GNSS time series, and formal combination with InSAR allows for velocity field and InSAR time series to be made available too.