

Session 1: Workshop Overview and State of the SCEC CGM

Tuesday 9 November 2021, 09:00–10:00 PST (UTC–8)
Moderators: Mike Floyd (MIT) and Katia Tymofyeyeva (JPL)
Reporters: Mike Floyd (MIT) and Katia Tymofyeyeva (JPL)

- CGM has consensus GNSS (survey and continuous) and InSAR time series by comparing, contrasting and trying to understand several input processing methodologies, either from other analysis centers (GNSS) or from contributors to the InSAR Working Group
 - GNSS time series operational (weekly updates) at MIT and served by web viewer developed at SCEC
 - InSAR time series currently end at Ridgecrest and are referenced to a fixed pixel
 - *Is extending the InSAR time series a priority, either back to pre-Sentinel-1 or post-Ridgecrest?*
 - *Is exploring methods to convert InSAR time series to 3-D displacements a priority?*
 - This was identified as an important consideration for modelers during chat/discussion
- Still lots to do, particularly moving time series to velocity solutions, including resolving differences and dealing with short- and long-term perturbations to linear trend
 - Hopefully “reconvene” GNSS Working Group to tackle this question
 - Questions raised in discussion regarding corrections applied to CGM time series and how this effects analysis, e.g. seasonal relationship to scale applied, how to deal with earthquakes in InSAR time series continuity
- This workshop intended to identify major goals and tasks as SCEC 5 ends and the “bridge period” begins
 - Important to consider limited time and resources
 - Set clear and realistic targets for one- to two-year timeframe

Session 2(a): Research Frontiers Relevant to CGM

Tuesday 9 November 2021, 10:00–10:50 PST (UTC–8)

Moderator: Niloufar Abolfathian (JPL)

Reporter: Eric Fielding (JPL)

- Xing Li and Sjonni Jonsson (KAUST): Using Sentinel-1 TOPS mode burst-overlap interferometry time series to measure along-track deformation. TOPS overlap only 1.5 km along-track but has large angle difference so sensitive to along-track (north) component. Empirical correction for ionospheric effects.
- Zhang Yunjun (Caltech): Using pixel offset tracking and time-series analysis on Sentinel-1 to measure both line-of-sight and along-track deformation. Less precise and coarser resolution than LOS InSAR but works in areas of large motion. Along-track much less precise than LOS due to Sentinel-1 TOPS mode and also affected by ionosphere
- David Bekaert (JPL): Described new NASA OPERA project addressing several needs for federal government agencies, including a planned InSAR deformation time series product for North America from Sentinel-1 and NISAR data. NASA products will be open. Development starting this year.

- Discussion session showed great interest in adding full 3D displacement products from SAR analysis for the future CGM, perhaps using Sentinel-1 BOI or pixel offset and data from other satellites such as ALOS-2
- Converting the new CGM InSAR v2 products from line-of-sight (LOS) to some horizontal and vertical components would aid visualization, even if it is less accurate due to assumptions. Need to discuss further best way or ways to do this.
- Maybe include laser scanning and optical image pixel offsets?

Session 2(b): Research Frontiers Relevant to CGM

Tuesday 9 November 2021, 11:10–12:00 PST (UTC–8)

Moderator: David Bekaert (JPL)

Reporter: Gareth Funning (UC Riverside)

- Jonathan Weiss (NGS): COMET have a similar project to CGM in Anatolia, S1 SBAS, combination with GNSS, strain rate estimation and a combined elastic/viscoelastic model of crustal deformation
- Yujie Zheng (Caltech): Non-zero phase closures in InSAR time series can be explained by multilooking of a heterogeneous process (probably related to soil moisture). Affects short time spans, particularly, and may bias velocities. It is possible to estimate and remove it.
- Angie Moore (JPL): The JPL group has made strides towards multi-GNSS processing. They are operationally processing GPS+Galileo orbits, and internally, they are also processing BeiDou and GLONASS. Main benefits will likely be in sub-daily processing, both in positions and for troposphere delay.

Session 3: CGM Products Demonstration and Testing

Wednesday 10 November 2021, 12:00–13:00 PST (UTC–8)
Moderators: Mike Floyd (MIT) and Kathryn Materna (USGS)

- CGM provide time series in two formats
 - GAGE's ".pos" format for GNSS, plus a script (http://geoweb.mit.edu/~floyd/scec/cgm/conv_gnss_ts.sh) for conversion to other common formats
 - HDF5 file and readers for InSAR (https://github.com/kmaterna/InSAR_CGM_readers_writers)
- Both are accessible either:
 - via a web interface (<http://www.scec.org/research/cgm-viewer>); or
 - directly (<http://geoweb.mit.edu/~floyd/scec/cgm/ts/> for GNSS or <https://drive.google.com/drive/folders/18SJy4jrDwFhENyD6RN1CIVaSWTUv-1yk?usp=sharing> for InSAR to date)
- CGM has designed an HDF5 file format for distributing InSAR results, along with a draft "manual" (documentation) and a Jupyter notebook of examples
- Please try the products and provide feedback at <https://forms.gle/SJAJiwm67Cj94iR39>

Session 4: CGM Design and Usability

Wednesday 10 November 2021, 09:00–10:00 PST (UTC-8)

Moderators: Mike Floyd (MIT), Katia Tymofyeyeva (JPL) and Kathryn Materna (USGS)

Reporter: Kang Wang (UC Berkeley)

❖ InSAR Breakout Session

- Realistic **errors/uncertainties**
- **Integration with GNSS** and build a **3D** deformation model
- Provide **different resolutions** and compare and validate with current model
- Extending time series to **beyond Ridgecrest**
- Incorporating UAVSAR, ALOS-1/2, and data from other satellites (TSX, ERS, Envisat)

❖ GNSS Breakout Session

- Time series analysis using various algorithms to compare and contrast approaches, and understand
 - Multiple products to serve community, e.g. **co/po**-seismic deformation, etc.
- What do we mean by **“interseismic velocity”**, from both a technical and modeling perspective?
 - If there are measurable, long-period velocity perturbations (“decades to centuries”) is this a “new interseismic velocity”?
- Resolve **discrepancies** between time series and velocity solutions from **various analysis centers**, and distribute a product most reflective of real Earth deformation, not artifacts too
 - What level of **“artifact”** we remove is an open question because it depends on desired use and anything we remove must be fit first, which requires some assumption about the process; “one person’s **signal** is another person’s **noise**”, etc.

❖ User Breakout Session

- HDF5 file works great -- suggestion to apply a common metadata format
- Users interested in using CGM products (velocities and time series) for both **research** and **educational** purposes, in tandem with other CXM products
- Suggestions included providing **3D decomposed** data product, adding more metadata about **data quality** (e.g. coherence for InSAR), **extending the domain** of the CGM products (including Baja and/or Northern CA), providing collaborative relationships with end-users for refining modeling approaches for their specific uses might be valuable, might be useful to have **multiple stages** of product (from “raw” to “more modeling included”).

Session 5: CGM Use Cases and Applications

Wednesday 10 November 2021, 10:15–11:30 PST (UTC–8)
Moderator: Xiaohua Xu (UT Austin)
Reporter: Junle Jiang (U. Oklahoma)

- **Donald Argus (JPL):** *Displacements of Earth's surface produced by changes in atmosphere and water*
 - Updated weather models (ECMWF) help remove atmospheric loading and improve GPS accuracy
 - New method (e.g., ICA) can potentially isolate GPS signals due to different physical mechanisms.
 - Need to better understand differences in SIO's GAMIT and JPL's GIPSY solutions (3 mm/yr in seasonal oscillations)
- **Fred Pollitz (USGS):** *Contributions of Geodetic Observations and Models to the 2023 Update to the National Seismic Hazard Model*
 - Use geodetic deformation models to estimate long-term slip rates, off-fault deformation, aseismic slip, etc.
 - Comparison of four western US deformation models: GPS Data assembly, fault creep model, ghost transient investigation (time-varying geodetic strain), and deformation model development.
- **Pietro Milillo (U. Houston):** *Interferometric Synthetic Aperture RADAR monitoring of infrastructure assets*
 - InSAR can be used for damage mapping and anomaly monitoring for structural health, e.g., bridge collapse.
 - PS- and neural network-based characterization of landslides in Italy and elsewhere, with validation data.
 - Efficient, automated processing of billions of data points (big data) are important for real-time applications.
- **Shimon Wdowinski (Florida International U.):** *Urban Geodesy: InSAR and GNSS monitoring of urban subsidence, building stability, and infrastructure*
 - Space geodetic techniques applied to land subsidence and infrastructural damage in Miami beach and Mexico city, and sinkhole activities in Florida.
 - Challenges (discontinuity in space/time) and opportunities in high-resolution InSAR in urban settings.

Session 6: The Future of the Community Geodetic Model

Wednesday 10 November 2021, 11:45–13:00 PST (UTC–8)

Moderator: Sylvain Barbot (U. Southern California)

Reporter: Carla Braitenburg (U. Trieste)

