InSAR 三维地表形变计算软件
SM-VCE 方法 MATLAB 工具包使用说明

Software for calculating 3-D displacements with InSAR
the Users' manual for the SM-VCE MATLAB toolkit

说明：此 MATLAB 工具包的核心即为 SM-VCE 方法，基于用户输入的多源 InSAR 观测数据，即可实现三维地表形变的计算。SM-VCE 方法表述的是一种基于地表应力应变模型（Strain model，SM）与方差分量估计（Variance component estimation，VCE）的 InSAR 三维地表形变测量方法，该方法已在多个实例中得到成功应用，包括 2007 年夏威夷基拉韦厄火山喷发、2016 年日本鸟取中部地震、2016 年新西兰凯库拉地震、2019 年美国加州 Ridgecrest 地震以及 2021 年我国青海玛多地震等，同时相关实例证实了 SM-VCE 方法得到的三维地表形变场精度明显优于传统方法。此外，此工具包也实现了传统的加权最小二乘方法，供用户选择使用。需要说明的是，由于实际情况复杂多变，此工具包内所设定的参数无法保证对所有实均可适用，具体情况还需具体讨论。我们非常欢迎各位同行使用此工具包，如有疑问或建议，也非常欢迎与我们沟通和反馈！

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Introduction　The core of this MATLAB toolkit is the SM-VCE method, and the 3-D surface displacements can be calculated based on this toolkit and the input InSAR measurements. SM-VCE method represents a method for measuring three-dimensional (3-D) surface displacements with InSAR based on strain model (SM) and variance component estimation (VCE). The superiority of the SM-VCE method has been demonstrated by several case studies, e.g., the 2007 Kilauea volcano eruption, the 2016 Central Tottori earthquake, the 2016 Kaikoura earthquake, the 2019 Ridgecrest earthquake, and the 2021

Qinghai Maduo earthquake. Also, the traditional weighted least square method (WLS) is provided. It should be noted that due to the complexity and variability of actual situations, the parameters in this toolkit cannot be guaranteed to be applicable to all situations, and the specific situation needs to be discussed. We welcome colleagues to use this toolkit. If you have any questions or suggestions, we are very glad to answer and communicate!

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如果您使用了此工具包，可引用下列论文作为支撑。

The following papers can be cited to support your work if this toolkit is used.

[1] Liu, J. H., Hu, J., Li, Z. W., Zhu, J. J., Sun, Q., & Gan, J. (2018). A Method for Measuring 3-D Surface Deformations With InSAR Based on Strain Model and Variance Component Estimation. IEEE Transactions on Geoscience and Remote Sensing, 56(1), 239–250. https://doi.org/10.1109/TGRS.2017.2745576

[2] Liu, J., Hu, J., Xu, W., Li, Z., Zhu, J., Ding, X., & Zhang, L. (2019). Complete Three-Dimensional Coseismic Deformation Field of the 2016 Central Tottori Earthquake by Integrating Left- and Right-Looking InSAR Observations With the Improved SM-VCE Method. Journal of Geophysical Research: Solid Earth, 124, 12099-12115. https://doi.org/10.1029/2018JB017159

[3] Hu, J., Liu, J., Li, Z., Zhu, J., Wu, L., Sun, Q., & Wu, W. (2021). Estimating three-dimensional coseismic deformations with the SM-VCE method based on heterogeneous SAR observations : Selection of homogeneous points and analysis of observation combinations. Remote Sensing of Environment, 255, 112298. https://doi.org/10.1016/j.rse.2021.112298

[4] 刘计洪, 胡俊, 李志伟, & 朱建军. (2021). InSAR 三维同震地表形变监测:窗口优化的 SM-VCE 算法. 测绘学报, 50(9). http://xb.sinomaps.com/CN/10.11947/j.AGCS.2021.20200610

[5] Liu, J., Hu, J., Li, Z., Ma, Z., Wu, L., Jiang, W., et al. (2021). Complete three-

dimensional coseismic displacements due to the 2021 Maduo earthquake in Qinghai Province, China from Sentinel-1 and ALOS-2 SAR images. SCIENCE CHINA Earth Sciences. https://engine.scichina.com/doi/10.1007/s11430-021-9868-9

SM-VCE 工具包使用说明（建议 MATLAB2018 及以后版本）：

（1）在计算三维形变之前，建议新建一个文件夹，然后将此工具包相关的文件拷贝至该文件夹下。

（2）InSAR 观测数据准备：所有的 InSAR 观测数据均在 SMVCE_DATA 文件夹下，具体请根据 SMVCE_DATA/data_information 内的介绍进行数据准备和信息更新。

（3）查看 SMVCE_main.m 主函数中的详细介绍，进行相应参数调整，然后运行 SMVCE_main.m 主函数即可。

相关 SM-VCE 计算函数在 SMVCE_code 文件夹下，具体实现过程可参见相关代码。为了更好地帮助各位同行使用此工具包，作者提供了示例数据，即 SMVCE_DATA 文件夹下的相关数据，相关参数即为此工具包的默认参数，直接运行 SMVCE_main.m 主函数即可。此工具包可在 Windows，Mac 或者 Ubuntu 系统下运行，Windows 下 MATLAB 浏览时，相应的中文注释可能会出现乱码，可使用记事本软件进行查看，然后全选，复制，粘贴至 MATLAB 编辑框即可。

常用参数调整：

① SMVCE_main.m 中的 windowsize 参数：此参数越大，结果会更平滑一些，但是相应的计算时间也会久一点，因此在实际案例中，可根据结果的噪声程度来对此参数进行调整；

② SMVCE_main.m 中的 flag_BOI 参数：示例数据中观测数据包含 1 个 BOI 观测值（flag_BOI(1)=1;），但是对于大多数情况可能没有 BOI 数据，用户需要将向量 flag_BOI 全部设为 0；

③ SMVCE_main.m 中的 flag_interWeight 参数：SM-VCE 方法在解算三维形变时，会用到周围点的 InSAR 观测数据，如果周围某一个点的观测值误差较大，则会影响三维形变的解算，此参数设为 1，则会对周围点的 InSAR

观测数据进行相对定权，降低误差较大观测值的权重。同样，此过程会在一定程度上降低程序的运行效率。

④ SMVCE_main.m 中的 flag_adpws 参数：有时候在震中区域，DInSAR 观测数据会失相干，这种情况下，如果将此参数设为 1，则会判断固定窗口内的 InSAR 观测值个数是否达到一定数量，如果未达到一定数量，则会将窗口扩大以包含更多的观测数据。如此一来，震中失相干区域也可利用周围点的数据进行三维形变解算。

User guidance for the SM-VCE toolkit (Recommend MATLAB2018 or higher version)

(1) It is recommended to make a new directory and put the SM-VCE toolkit-related files into the new directory.

(2) Prepare the InSAR measurements: All the InSAR measurements should be put in the directory of SMVCE_DATA, and please the file of SMVCE_DATA/data_information for the introduction of how to prepare data.

(3) Please carefully view the parameter introduction in the main function SMVCE_main.m, and then adjust the parameters according to the real cases, and finally run 'SMVCE_main.m'.

The detailed functions of the SM-VCE method are in the directory SMVCE_code. For users better familiarizing with this toolkit, we provide a DEMO case, i.e., the data in SMVCE_DATA, and users can directly run the main function 'SMVCE_main.m' to get the 3-D displacement field. This toolkit can be implemented in both windows and ubuntu system, but the encoding of the Chinese annotation may be problematic in the MATLAB software in the Windows system. In this case, users can use the software 'Notepad' within the windows system to open the matlab files, and copy the code to the MATLAB compiler.

Guide for some parameters in SMVCE_main.m:

① windowsize：the larger this variable, the smoother the 3-D displacements, and also more time is needed to calculate the result.

② flag_BOI: a BOI measurement is included in the DEMO, therefore there is a code flag_BOI(1)=1; If no BOI measurement is available in other

cases, please set the vector flag_BOI(:)=0;

③ flag_interWeight: sometimes there are some measurements (very few) with large errors, in this case, these low-quality measurements would degrade the 3-D displacements. If we set this parameter equal to 1, the weight of those low-quality measurements within a window would be set very small to decrease the effect on the 3-D displacements.

④ flag_adpws: if this parameter is set 1, the following case would be improved. For example, in some area (the near-fault area in an earthquake) the DInSAR has no valid data, it is challenging to calculate reliable result. In this case, if we adaptively enlarge the windowsize, it is possible to include more measurements for calculating the 3-D displacements at those point with no valid measurements.

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