Jet Propulsion Laboratory
California Institute of Technology

# CARD4L specification for a Geocoded Single Look Complex SAR data product

Bruce Chapman[1], Howard Zebker[2], Piyush Agram[1], Sean Buckley[1], Marco Lavalle[1]
[1]Jet Propulsion Laboratory, California Institute of Technology
[2]Stanford University

# Interest in InSAR

- Due to the diverse and numerous applications of InSAR being developed, non-SAR experts are increasingly wanting to process and analyze InSAR data for themselves.
- But the processing of InSAR data remains challenging for non-specialists, which is limiting its potential for widespread use.

# Geocoded SLCs

Proposed by Zheng and Zebker (2017)

1. adopt motion compensation techniques to resample SLC images with respect to an ideal reference orbit
2. separate the residual topographic phase contributions into parts dependent only on individual SLC acquisitions
3. generate topography-compensated images directly in latitude–longitude coordinates (or easting/northing, …)

# InSAR challenges

- Familiarity required with methods of radar processing
- With the advent of missions like Sentinel-1 and NISAR, **the total number of radar interferograms that can be generated for most locations on earth can easily be in the thousands**

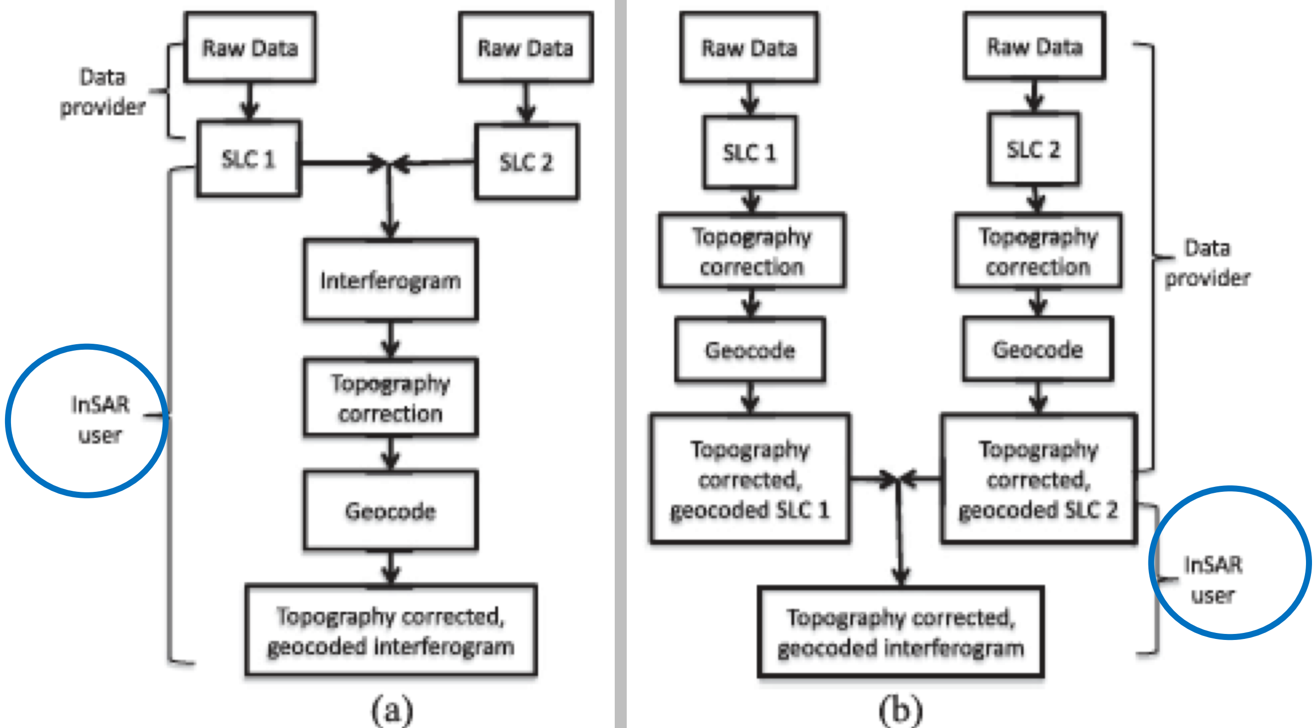
# GSLC Analysis Ready INSAR Data

- Simplify generation of interferograms by non-specialists
- Reduce volume of data that must be downloaded
  - GSLCs, not all the interferograms
- Get geocoded results
- More efficient  processing as topography correction is done at SLC level.

# Comparison of processing flow

Traditional

GSLC




Zheng and Zebker, 2017

- GSLC Interferograms are still subject to
  - Insar phase noise
  - Atmospheric noise
  - Decorrelation
  - Phase unwrapping issues
- But Zheng and Zebker found the RMS difference of deformation time series between the two workflows to be around 2 mm for both an ALOS time series and a COSMO-SkyMed time series for Kilauea Hawaii.

# GSLC ARD issues

- This product will be analysis ready, but cautionary for novice users, as users will still need to properly interpret the meaning of the phase.
- Could facilitate data fusion by defining a common grid for geocoding.
- Target product would incorporate atmospheric models and ionospheric corrections.
- The product will be encoded in a way unfamiliar to many users (complex numbers) that may be unsupported by a users favorite software package.

# CARD4L

## First draft product specification

- The algorithms must be specified in the metadata
- The amplitude and phase of the radar backscatter is stored as a complex number.  Target requirement is that the square of the magnitude of each pixel is $\gamma^o$.

- Other metadata similar to radar backscatter CARD4L.

# General metadata requirements as similar as possible to other CARD4L product specs

## Requirements

### 1. General Metadata

*These are metadata records describing a distributed collection of pixels. The collection of pixels referred to must be contiguous in space and time. General metadata should allow the user to assess the overall suitability of the dataset, and must meet the following requirements:*

| | Item | Threshold (minimum) requirements | Target (desired) requirements |
|---|---|---|---|
| **1.1** | **Traceability** | Not required. | Data must be traceable to SI reference standard. For further information see, for example, http://l-a-b.com/information/traceability/ |
| **1.2** | **Metadata machine readability** | Metadata is provided in a structure that enables a computer algorithm to be used to consistently and automatically identify and extract each component part for further use. | As threshold, but metadata is formatted in accordance with ISO 19115-2. |
| **1.3** | **Data collection time** | The start and stop time of data collection is identified in the metadata, expressed in date/time, to the second, with the time offset from UTC unambiguously identified. | Acquisition time for each pixel is identified (or can be reliably determined) in the metadata, expressed in date/time at UTC, to the second. |
| **1.4** | **Geographical area** | The surface location to which the data relates is identified, typically as a series of four corner points, expressed in an accepted coordinate reference system (e.g.,WGS84). | The geographic area covered by the observations is identified specifically, such as through a set of coordinates of a closely bounding polygon. The location to which each pixel refers is identified (or can be reliably determined) expressed in projection coordinates with reference datum. |
| **1.6** | **Map projection** | The metadata lists the map projection that has been used, | As threshold |

Per pixel metadata specifies many optional parameters to improve the usefulness of the GSLC data products (but are not even target requirements)

## 2. Per-pixel metadata

*The following minimum metadata specifications apply to each pixel. Whether the metadata are provided in a single record relevant to all pixels, or separately for each pixel, is at the discretion of the data provider. Per-pixel metadata should allow users to discriminate between (choose) observations on the basis of their individual suitability for application.*

| | Item | Threshold (minimum) requirements | Target (desired) requirements |
|---|---|---|---|
| 2.1 | **Metadata machine readability** | Metadata is provided in a structure that enables a computer algorithm to be used to consistently and automatically identify and extract each component part for further use. | As threshold, but metadata is formatted in accordance with relevant international standards (ISO 19115-2). |
| 2.2 | **No data** | Pixels or grid cells that do not correspond to an observation ('empty pixels') are clearly flagged | As threshold. |
| 2.3 | **Azimuth time polynomial grid** | Optional | As threshold. |
| 2.4 | **Slant range polynomial grid** | Optional | As threshold. |
| 2.5 | **Incidence Angle grid** | Optional | As threshold. |
| 2.6 | **Azimuth Angle grid** | Optional | As threshold. |
| 2.7 | **Elevation Angle grid** | Optional | As threshold. |
| 2.8 | **Thermal Noise** | Such as from a lookup table. | As Threshold |
| 2.9 | **sigma0 conversion** | Such as from a lookup table. | As Threshold |
| 2.10 | **gamma0 conversion** | Such as from a lookup table. | As Threshold |
| 2.11 | **Atmospheric phase correction** | Optional | Specify atmospheric model. |
| 2.12 | **Ionospheric phase correction** | Optional | Specify correction |
| 2.13 | **estimate of uncertainty in InSAR phase** | Due to estimated errors in DEM. Ref: Zheng and Zebker, 2017 | As Threshold |

Radiometric corrections to $\gamma^o$ and $\sigma^o$ are provided in metadata as threshold requirements.

This will allow this product to be used for high resolution backscatter analysis in addition or complementing InSAR analysis.

## 3. Radiometric corrections

*The following requirements must be met for all pixels in a collection. The requirements indicate the necessary outcomes and to some degree the minimum steps necessary to be deemed to have achieved those outcomes. Radiometric corrections must lead to normalised measurement(s) of backscatter intensity.*

| | Item | Threshold (minimum) requirements | Target (desired) requirements |
|---|---|---|---|
| **3.1** | **Measurements** | Amplitude and phase of radar backscatter, stored as complex number. Corrections to sigma0 and gamma0 provided in metadata. | As threshold. |

Geometric corrections:

Similar to other CARD4L specs

## 4. Geometric corrections

*Geometric corrections must place the measurement accurately on the surface of the Earth (that is, geolocate the measurement) allowing measurements taken through time to be compared.*

| | Item | Threshold (minimum) requirements | Target (desired) requirements |
|---|---|---|---|
| 4.1 | Accuracy | Sub-pixel accuracy is taken to be less than or equal to 0.2-pixel radial root mean square error (rRMSE) or equivalent in Circular Error Probability (CEP) relative to a defined reference.<br><br>Relevant metadata must be provided under 1.7 and 1.8 (Geometric correction and Geometric accuracy)<br><br>A consistent gridding / sampling frame is used, including common cell size, origin, and nominal sample point location within the cell (centre, ll, ur)<br><br>*Note 1. Accurate geolocation is a prerequisite to radar processing to correct for terrain. To enable interoperability between radar sensors absolute accuracy is required. Orbit ephemeris updates (precise ephemeris) are required prior to any orthorectification steps to ensure accuracy.* | Sub-pixel accuracy is achieved relative to an identified absolute independent terrestrial referencing system (such as a national map grid).<br><br>Relevant metadata must be provided under 1.7 and 1.8 (Geometric correction and Geometric accuracy) |

Procedural example is provided (from the NISAR algorithm spec).

## Procedural examples

The GSLC product is derived from the range-Doppler SLC product using a DEM and the MOE state vectors and output in the map projected system. The geocoded SLCs will be flattened with respect to a reference orbit to eliminate SLC topographic phase contributions. The spacing of the GSLC product in East and North directions is comparable to the full resolution original SLC product. The GSLC product can be directly overlaid on a map or combined with other similar GSLC products to derive interferograms and create change maps, for example.

**NISAR example from NISAR NASA SDS Algorithm Theoretical Basis Document (Piyush Agram, Marco Lavalle and Sean Buckley, 2018).**

In the first stage, an external DEM and precise orbits are used to estimate an offset field for resampling the source SLC products on to the geocoded grid.

We use the reverse geometry mapping algorithm performed as follows:

1. Identify the bounding box in geocoded domain (i.e. UTM) for a given source SLC product and fetch the relevant DEM.
2. Interpolate the DEM to posting corresponding to the desired output.
3. For each pixel in the interpolated DEM, identify the corresponding location in radar geometry using the reverse geometry mapping algorithm, and save this mapping.

Resampling of the original SLC product onto the geocoded DEM grid can be accomplished using a variety of interpolators. Resampling of a single pixel can be broken down into the following steps:

1. Read a block of data in the neighborhood of the pixel of interest. The neighborhood should be large enough to accommodate the support of the chosen interpolator.
2. Demodulate the block of data using the Doppler Centroid polynomial to baseband the complex valued data.
3. Interpolate the base-banded block of data using interpolator of choice.
4. Compute the azimuth carrier at the interpolated pixel location from the Doppler Centroid Polynomial, and add it back to the interpolated value.

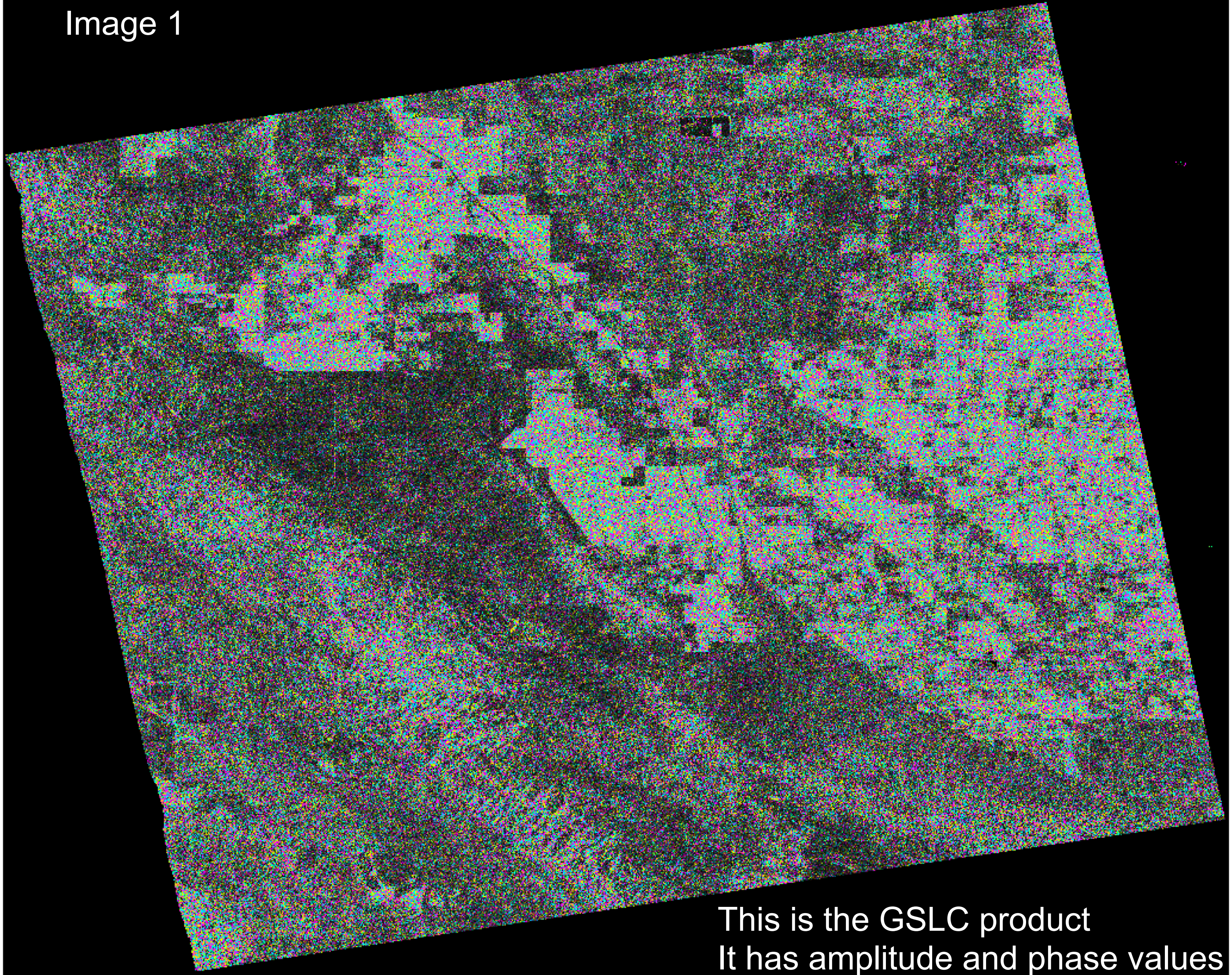
The choice of interpolator plays a significant role in determining the quality of the final interferometric products [Hanssen and Bamler, 1999]. A 16-point truncated sinc for resampling

# Sample data set will also be provided

- Three ALOS-2 images over southern California agriculture and oil extraction location (Lost Hills, California)
  - 20160929
  - 20170928
  - 20171123

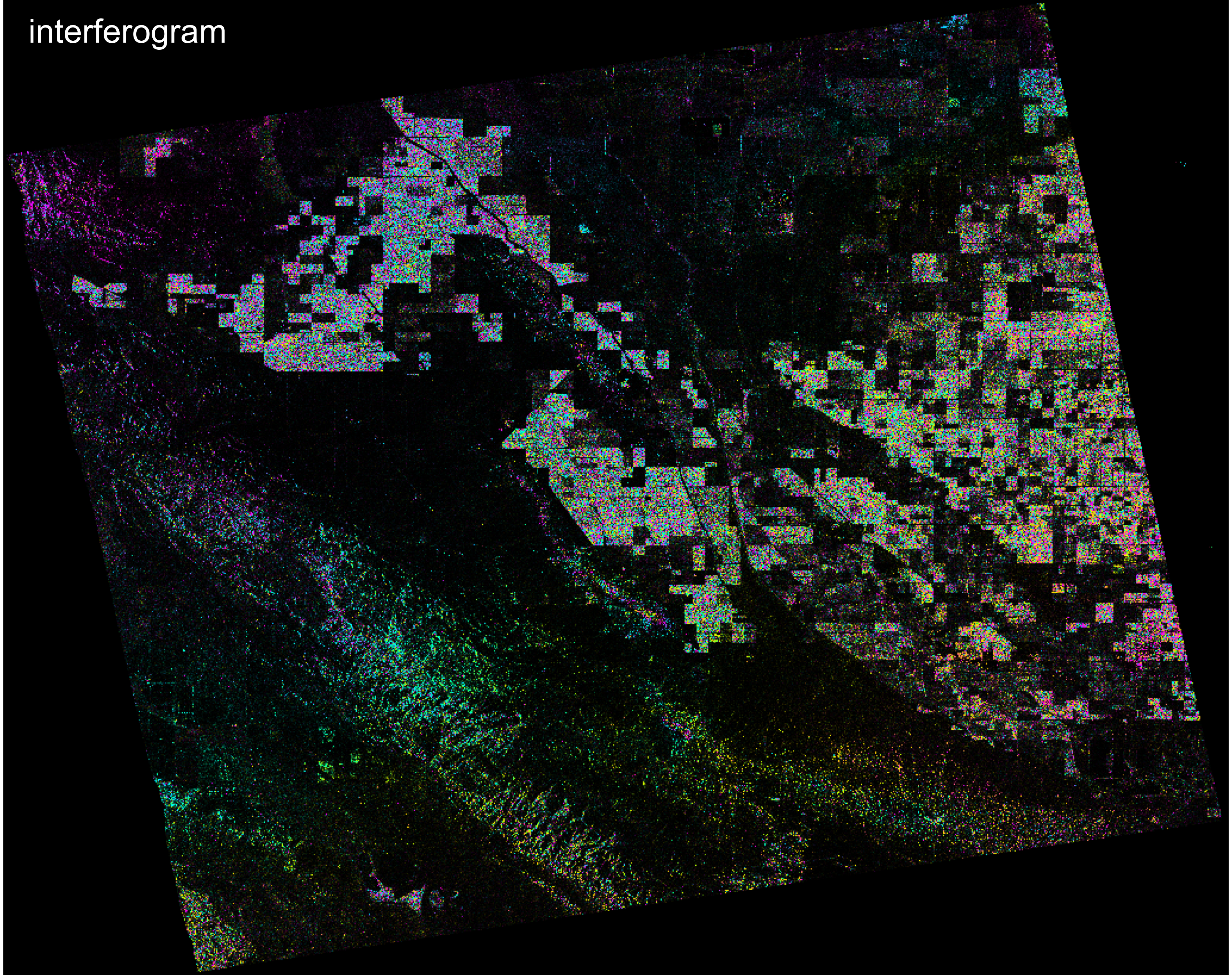
- Howard Zebker processed and provided these products.
- Metadata for the data products are still being incorporated into the sample data.

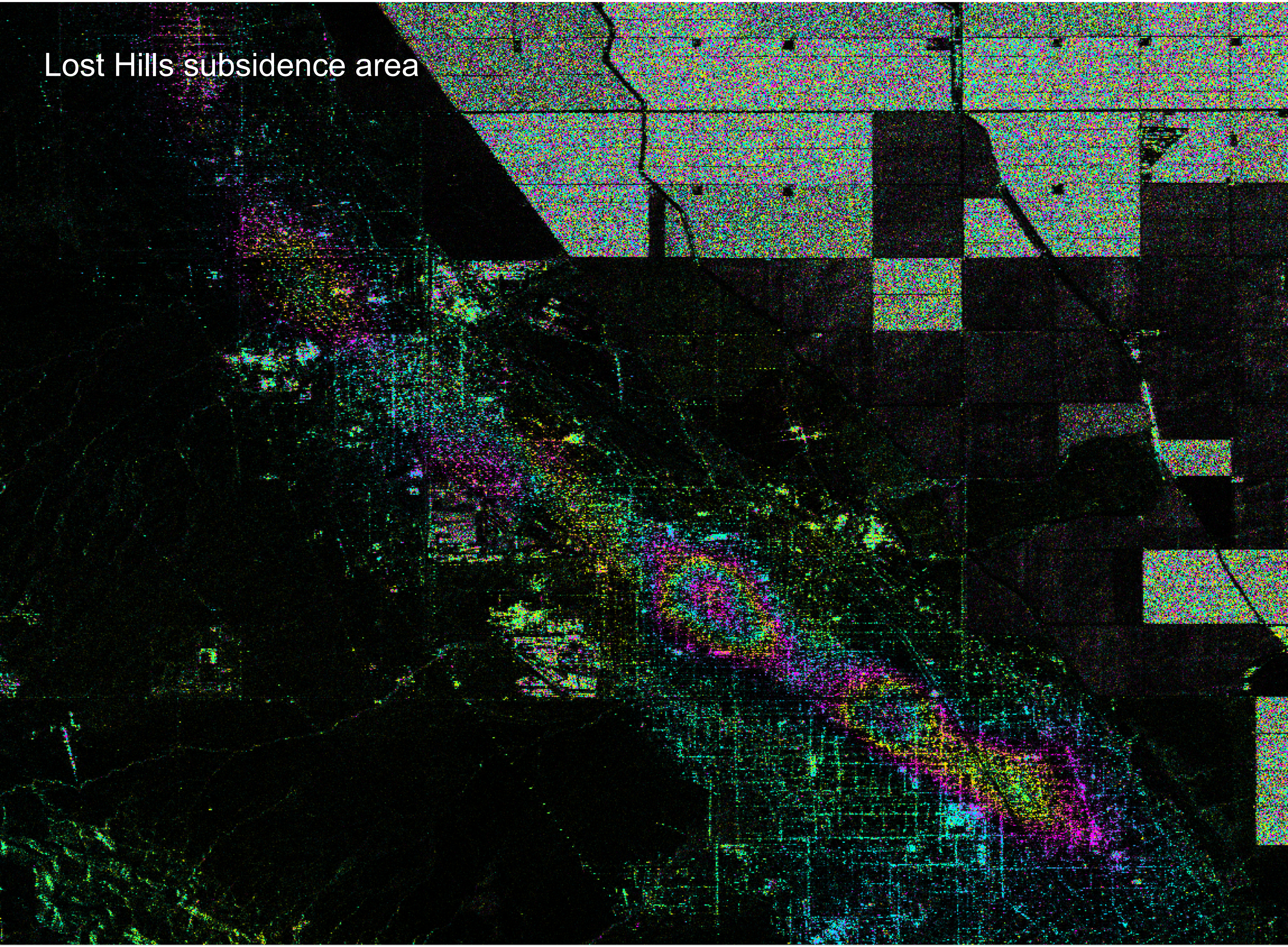
Image 1



This is the GSLC product
It has amplitude and phase values

interferogram




Lost Hills subsidence area

# Reference


- *Zheng, Y., & Zebker, H.A. (2017). Phase Correction of Single-Look Complex Radar Images for User-Friendly Efficient Interferogram Formation. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 10, 2694-2701.*

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California Institute of Technology

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