# Syllabus

**Course Title:**

InSAR Processing and Time-Series Analysis for Geophysical Applications: InSAR Scientific Computing Environment (ISCE), ARIA Tools, and MintPy

**Short Summary:**

This course will cover basic InSAR theory, basic geophysical modeling, InSAR processing with JPL/Caltech InSAR Scientific Computing Environment (ISCE), and time-series InSAR processing with archived interferometric products using ARIA Tools and MintPy, with applications to example geophysical problems.

**Instructors:**

- Paul Rosen (JPL)
- Piyush Agram (Descartes Lab)
- David Bekaert (JPL)
- Andrea Donnellan (JPL)
- Scott Hensley (JPL)
- Heresh Fattahi (JPL)
- Franz Meyer (U Alaska Fairbanks)
- Scott Baker (UNAVCO)
- Gareth Funning (UC Riverside)

- Hilarie Davis (TLC)

**Brief Agenda:**

- Pre-course self-directed: math, unix, python, plotting, numpy basics, downloading data, cloud environment, GIS using GDAL, software installation, SAR Theory
- Day 1: Geophysical modeling, InSAR theory, Stripmap InSAR processing with ISCE2 including lab exercises and discussion of ionospheric corrections
- Day 2: Interpreting interferograms, TOPS Processing
- Day 3: Map projections, preparing data for modeling, tropospheric/ionospheric errors
- Day 4: Time-series theory, stack processing, ARIA tools
- Day 5: Time-series analysis using MintPy

**Prerequisite, Computers and Data:**

- Students should have some facility with mathematical concepts such as complex numbers, trigonometry, integration and differentiation.
- Students will be expected to know basic Unix/Linux command line usage and basic Python programming.

- Students should review materials from 2019 InSAR Theory and Processing training courses.
- Students should review online documentation and tutorial materials available for ISCE2.
- Students must apply for a NASA earthdata account and are able to access ALOS PALSAR and Sentinel-1, and Get Ready for NISAR datasets via ASF.
- Students, once accepted to the course, must apply for an account on OpenSARLab at opensarlab.asf.alaska.edu

## Virtual Participation:

This course will be conducted entirely as a virtual course. In addition to 4 hours of daily on-line instruction, daily virtual office hours will be scheduled, as well as pre-course self-directed preparation.

## Assessment:

In-course homework and processing assignments will be assigned. There will also be a post-course project. For those requiring graduate course credits, these assignments are considered mandatory.

**Pre-course Content:** Students provide evidence of task completion (screenshots, files, …) and comfort level rating from 1-4 level

- Needed Math – complex numbers, trig functions, simple integration, derivatives (Scott H)
    - Expected outcome: Students have sufficient familiarity to follow the course material, which relies on these mathematical concepts to describe the theory.
    - Assessment: Short problem set for student to self-assess if they are ready
    - Evidence: Print-out of final problem in problem set, and statement of comfort level (1-4)

- Accessing and Working within the OpenSARLab (OSL) (Franz)
    - Expected outcome: Students know how to bring up, close down OSL, navigate the folder structure, open terminals, shutdown notebooks and terminals, and basic jupyter cell and run control
    - Assessment: Short exercise to start up OSL, navigate to a notebook, run it, open a terminal, type some output from the notebook run, shutdown notebook and terminal, and logout. Student self-assessment of comfort level
    - Evidence: Run trivial notebook - go to terminal to print the file that was created - send screenshot

- Geographic Information Science using GDAL (Scott B./ Piyush)
    - Expected outcome: Students learn how to perform typical GIS operations like coordinate transformation, projections, etc. using GDAL

- Assessment: Some exercise to perform some operations on canned data and display the output. Student self-assessment of comfort level
- Evidence: Perform a canned reprojection and make a jpeg.

- Installation of ISCE using conda, including containerization, and running containers through things like docker (Scott B.)
  - Expected outcome: Students learn how to follow the conda installation recipe for ISCE2 and do some troubleshooting, and where to go to get help when things don't go well, and how to find and run docker containers, and how to install docker on mac and linux.
  - Assessment: Student self-assessment of comfort level
  - Evidence: Run one of the apps after install: stripmapApp.py --help and take screenshot

- Data Search and Access (Scott B.)
  - Expected outcome: Students know the SAR platforms collecting data, where relevant SAR data can be found (data files, orbits, ancillary datasets like DEMs) , and understand how to get access to the data and which tools are available to do so (SSARA, Vertex, ARIA Tools…). Students also learn how to intelligently limit the search to just the frames they want
  - Assessment: Short exercise to download ALOS and S-1 data with filters to students know how to get just the frames they want, and no extras. Student self-assessment of comfort level
  - Evidence: Download product and share kmz

- SAR Imaging Theory (Optional) (Rosen)
  - Expected outcome: Students learn the basics of SAR imaging by processing an image step by step from simulated raw data to full imagery using range-doppler and backprojection focusing methods.
  - Assessment: None – no exercises
  - Evidence: N/A

- SAR Theory - Phenomenology (Rosen/Hensley)
  - Expected outcome: Students learn the basics of phenomenology, including speckle, radar equation, wavelength dependence, polarization, layover, shadow
  - Assessment: None – no exercises
  - Evidence: N/A

**<u>Monday, Aug 10 (Pacific Time)</u>**

*<u>Overview of day</u> (theme, purpose) Overview of whole process from modeling to processing.*

10:00 – 10:15 Introductions / Agenda Review Funning

10:15 – 10:50 Recap of OSL/downloading training Rosen/Meyer

10:50 – 11:00 Break

11:00 – 11:50 Module: Geophysical Modeling with InSAR/GNSS/Geodetic Data Funning/Donnellan

- Learning outcome: Understand how geophysical processes affect surface deformation and what that deformation looks like in InSAR and GNSS observations
- Assessment: Homework #2 on modeling
- Evidence: Printout of modeling results from Homework #2

11:50 – 12:00 Break

12:00 – 12:50 Module: InSAR theory Rosen/Hensley

- Learning outcome: A working knowledge of the geometric aspects of InSAR; the relationship between range change, phase change, and surface displacement or topography, critical baseline and other interferometric performance metrics and influencers; the rudiments of interferometric correlation and its utility in error analysis or change mapping
- Assessment: Problem set to alter parameters in the notebook to see the effects of changes on interferometric performance
- Evidence: Printout of revised notebook plots showing altered parameter results

12:50 – 13:00 Break

13:00 – 13:50 Module: Stripmap Data Processing – Interferometry Fattahi/ All

- Learning outcome: An ability to run stripmapApp.py, understand how to get help, how to step through the workflow, how to alter meaningful parameters, and how to evaluate the results for whether things worked well or not.
- Assessment: Homework #1 on running stripmapApp.
- Evidence: Printout of final geocoded products

13:50 – 14:00 Describe homework *Homework revisits key concepts of the day*

1. Homework 1: Run an InSAR pair using stripmapApp
2. Homework 2: Run modeling notebook example with synthetic data playing with error sources

**Tuesday, Aug 11 (Pacific Time)**

*Overview of day (theme, purpose)*

10:00 – 10:50 Review homework results and problems encountered All
10:50 – 11:00 Break
11:00 – 11:50 Module: Interpreting a co-seismic interferogram (Paper exercise) Funning

- Learning outcome: Become familiar with wrapped phase, noise properties of interferograms, how to unwrap by hand and relate it to the deformation event.
- Assessment: Homework #2 on modeling. Here, the student needs to interpret the results and describe the confidence of the inverted parameters based on the quality of the input.
- Evidence: Screenshot of final result and paragraph narrative of confidence statement.

11:50 – 12:00 Break
12:00 – 12:50 Module: TOPS Data Processing – Pt 1 Agram/ All

- Learning outcome: An ability to run stripmapApp.py, understand how to get help, how to step through the workflow, how to alter meaningful parameters, and how to evaluate the results for whether things worked well or not.
- Assessment: Homework #1 on running TOPSApp
- Evidence: Printout of final geocoded products

12:50 – 13:00 Break
13:00 – 13:50 Module: TOPS Data Processing – Pt 2 Agram/ All

- Learning outcome: See Part 1
- Assessment: See Part 1
- Evidence: See Part 1

13:50 – 14:00 Describe homework

1. Homework 1: Run topsApp on sample data
2. Homework 2: Run modeling notebook example with real data from topsApp

**<u>Wednesday, Aug 12 (Pacific Time)</u>**
*<u>Overview of day</u> (theme, purpose)*

10:00 – 10:50 Review homework results and problems encountered All
10:50 – 11:00 Break
11:00 – 11:50 Module: Raster Data Tiling + Map Projections Agram/ Baker

- Learning outcome: Develop an understanding of manipulation of raster image data and their metadata, including the reasons data sets are projected in different ways to better capture a particular aspect of a spherical data set represented in a 2-dimensional space, most important projections, how to transform between projections.

- Assessment: In class manipulation of tiled data converting between specified projections in a notebook.
- Evidence: Printout display of final result.

11:50 – 12:00  Break
12:00 – 12:50  Module: Review Preparing InSAR data for modeling module   Funning

- Learning outcome: Develop an understanding of what constitutes a properly prepared InSAR data for modeling, including map projections, components of deformation specified, unwrapping requirements, error layers for input, etc.
- Assessment: Homework #1 on InSAR modeling inputs
- Evidence: Completed homework

12:50 – 13:00  Break
13:00 – 13:50  Module: Tropo intro / Ionosphere + Split Spectrum   Fattahi

- Learning outcome:  Develop and understanding of the typical signatures of the troposphere and ionosphere in InSAR data, its spatial and temporal variability, wavelength dependence (or not), ways to estimate or model, and expected improvements.
- Assessment: Execute the self-directed notebook and inspect the result
- Evidence: 1-paragraph summary of the outcomes of running the notebook and how the student thinks it will influence InSAR modeling

13:50 – 14:00  Describe homework   Fattahi/ Agram
14:00 – 14:15  Group webcam picture

1. Homework 1: Prepare some InSAR data for modeling
2. Self-directed: Troposphere + GACOS  module

**<u>Thursday, Aug 13 (Pacific Time)</u>**
*<u>Overview of day</u> (theme, purpose)*

10:00 – 10:50  Review homework results and problems encountered   All
10:50 – 11:00  Break
11:00 – 11:50  Module: Time-series theory   Agram

- Learning outcome: Develop an understanding of how multiple time samples of an image can be used to track time-dependent deformation, reduce noise in estimates, or both. Describe methods of time series, including SBAS, PS, and hybrid approaches
- Assessment: Homework #1 on stack creation
- Evidence: Homework results - final plots of baselines/time diagram, coherence matrices, etc.

11:50 – 12:00 Break

12:00 – 12:50 Module: ARIA tools – Cropping and Stitching InSAR products Bekaert/All

- Learning outcome: Develop a facility for exploring the Get Ready For NISAR ARIA products at the ASF, downloading processing interferograms, and manipulating interferograms to create a stack ready for time-series analysis.
- Assessment: Homework #1 on stack creation
- Evidence: Homework results - final plots of baselines/time diagram, coherence matrices, etc.

12:50 – 13:00 Break

13:00 – 13:50 Module: Interferogram stacks: Temporal-spatial statistical considerations Bekaert

- Learning outcome: Drill down further in time-series to an understanding of what to expect if a stack of interferograms is presented to a time-series analysis package. This includes temporal coherence of individual PS scatterers and distributed scatterers, and how these considerations impact analysis.
- Assessment: Homework #1 on stack creation
- Evidence: Homework results - final plots of baselines/time diagram, coherence matrices, etc.

13:50 – 14:00 Describe homework

1. Homework 1: Create Stack

**<u>Friday, Aug 14 (Pacific Time)</u>**

*<u>Overview of day</u> (theme, purpose)*

10:00 – 10:50 Review homework results and problems encountered All

10:50 – 11:00 Break

11:00 – 11:50 Module: Intro to MintPy Fattahi/All

- Learning outcome: Develop an understanding of the capabilities of MintPy, expected inputs and possible outputs, and control parameters
- Assessment: Final project that brings together everything in previous lectures, including a time series analysis using MintPy, followed by an inversion of a specific model for one or two interferograms in the stack. Could pick something like a dyke intrusion event, and analyze nearest pair and other pairs spanning the event and see how the models differ.
- Evidence: Final project output - plots of derived deformation time function; model parameters derived for individual time-step.

11:50 – 12:00 Break

12:00 – 12:50 Module: Time Series Analysis with MintPy Fattahi/All

- Learning outcome: Develop an intuition in running and examining the results from MintPy
- Assessment: Final Project - see above
- Evidence: Final Project Output - see above

12:50 – 13:00 Break
13:00 – 13:50 Module: Intro/preparing data for stack processing Agram/Baker

- Learning outcome: Learn how to prepare stacks from scratch, not relying on ARIA tools.
- Assessment: Final Project - see above
- Evidence: Final Project Output - see above

13:50 – 14:00 Course assessment using mentimeter

Self-directed: Time Series Analysis with MintPy – Error analysis and noise reduction
Self-directed: Visualization and exporting results
Self-directed: Sentinel Stack processing example