InSAR Scientific Computing Environment (ISCE): An Earth Science SAR Processing Framework, Toolbox, and Foundry

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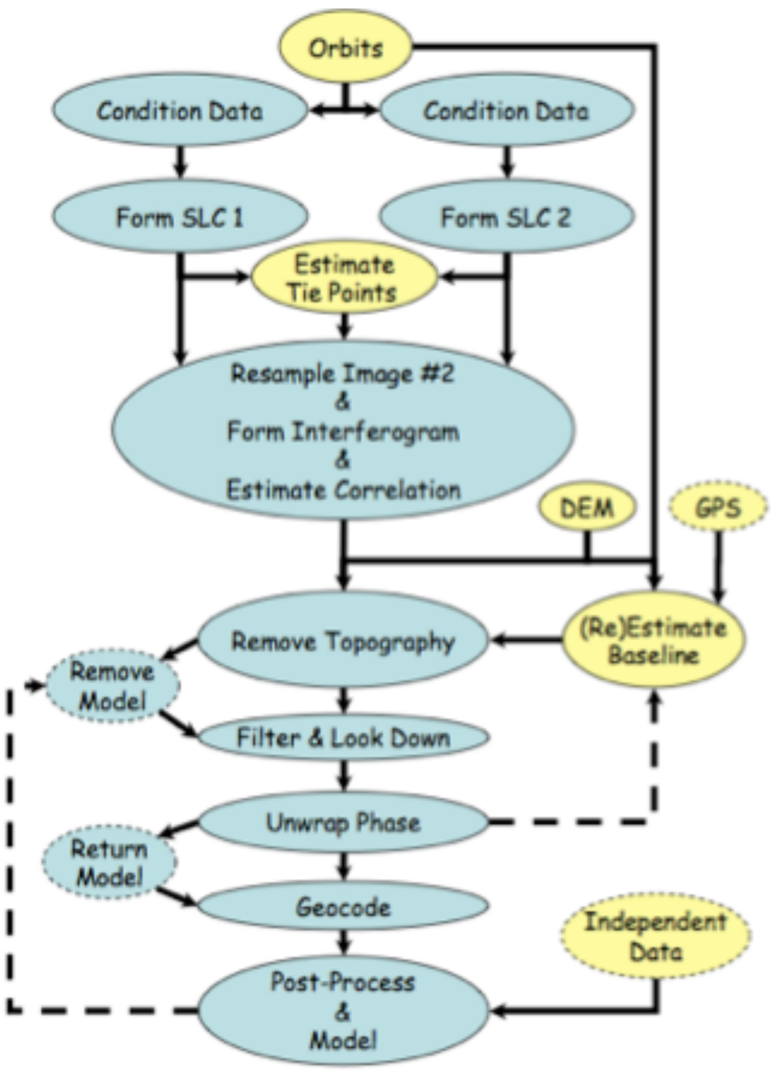
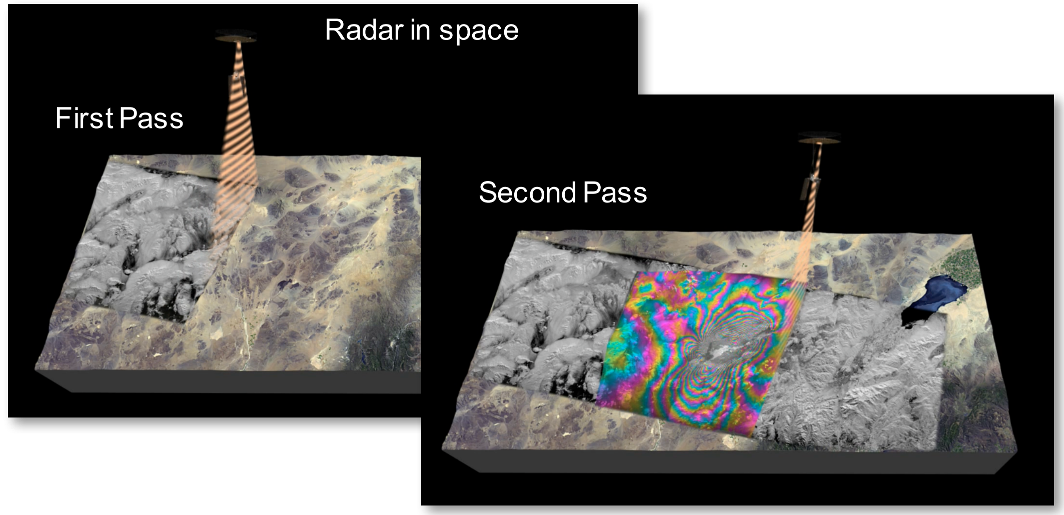
Outline

- Introduction
- Technology and Functionality Description
- ISCE Support of:
  - individual users
  - ARIA production system (for disaster response and other scientific studies)
  - NISAR production system algorithmic core as well as NISAR data users
- ISCE as Foundry for onboarding new InSAR and science applications workflows. Current examples : PLAnT, Sentinel TOPS mode
- Vision for ISCE architecture
  - What international missions it supports and how
  - How does it support the user community

Interferometric Synthetic Aperture Radar (InSAR)
From Recipes to Reconfigurable Flow






```
260:/Users/parosen/Projects/CSK/hawaii> python3
>>> import isce
>>> from applications.insarApp import Insar
>>> a = Insar()
>>> a.configure()
2014-10-18 17:47:51,008 - isce.insar - INFO - ISCE VERSION = 2.0.0_201409, RELEASE_SVN_REVISION = 1612,RELEASE_DATE = 20140918, CURRENT_SVN_REVISION = 1647

>>> a.rangeLooks=4
>>> a.run()

    Insar Application:
    Implements InSAR processing flow for a pair of scenes from
    sensor raw data to geocoded, flattened interferograms.

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.
.
```

Fixed Prescriptive Flow → **Flexible "Sandbox" ISCE Flow**

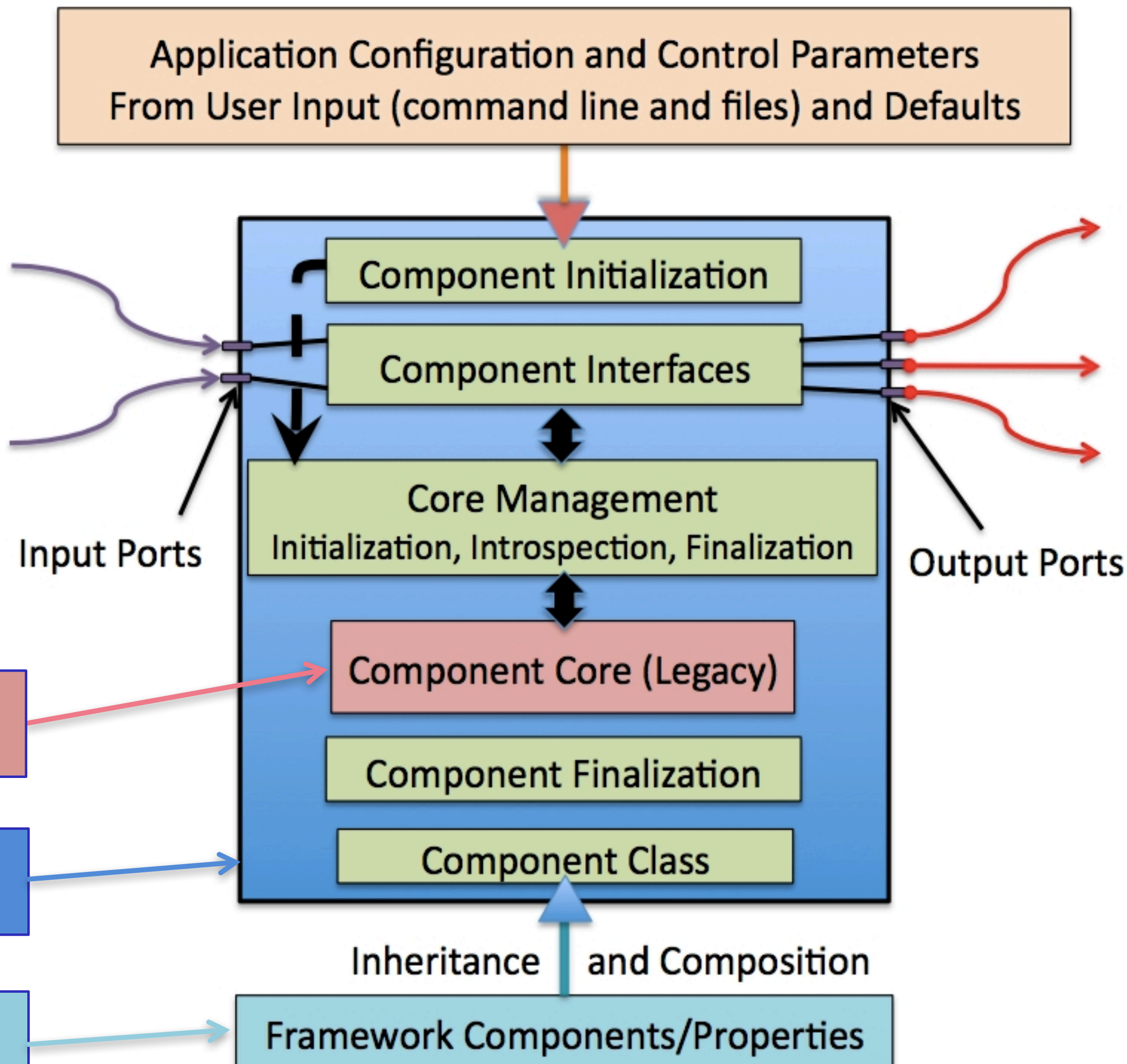
ISCE Algorithms

- Created accurate and fast algorithms based on GEOSAR, SRTM, RoiPAC heritage
- Advantages of improved accuracy and speed:
  - Enable InSAR and time series methods with precise SLC alignment requirements
  - Straightforward merging SAR data with other types
  - Feasible processing of dozens of scenes by a desktop user
- Approach
  - Define a rigorous geometric framework tied to local spherical coordinate system (as used in SRTM and GeoSAR)
    - (Moving towards zero-Doppler, locally cartesian approach used in RoiPAC package and other processing packages (as an option).
  - Adjust collection of images to a common reference trajectory
  - Condition data for ingestion in post-processing time-series applications such as GIAnT

The Architectural Core of ISCE

By adopting a general object oriented framework for processing, ISCE

- Enables extensibility and flexibility by abstracting functions that are typically embedded in scientific codes
- Allows straightforward inclusion of scientific methods developed over many years without redevelopment of algorithms



Legacy code in Fortran, C, or other domain expert language

Object oriented processing components in Python 3.X

Framework components in Python 3.X and C++

ISCE Features

- Object orientation using Python on top of legacy and new c/c++ and Fortran functions, subroutines, and classes.
- A common hierarchical structure for defining components and applications
- An Image API & I/O API to abstract access to data and metadata
- Runtime polymorphism through factory pattern creation of components
- Provenance through xml metadata and python *pickle* mechanisms

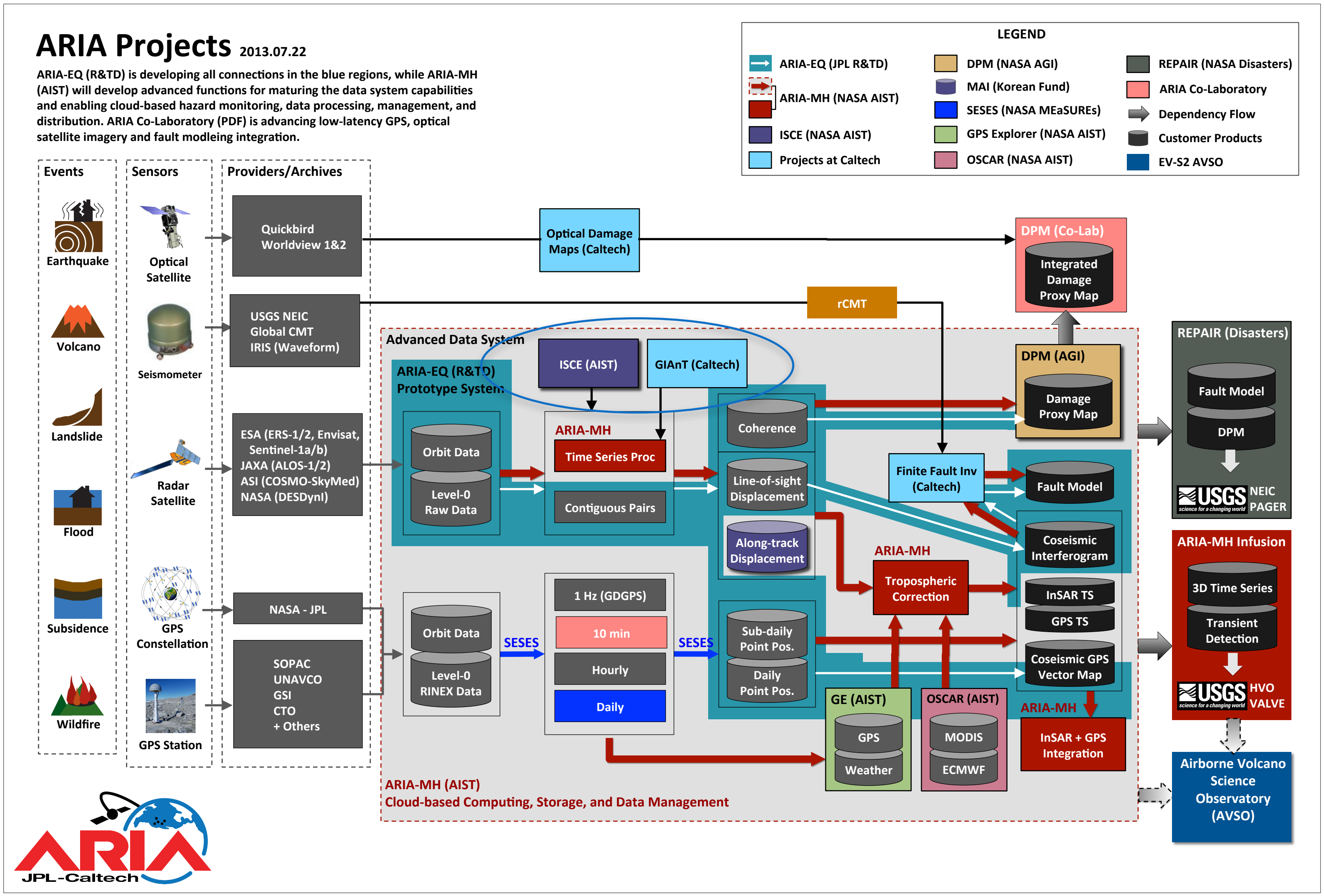
Code Status

- Code includes Components and workflows to support pairs or stacks of raw or focused strip map inputs to flattened, unwrapped, geocoded products from these sensors,
  - ALOS-1, ALOS-2, Cosmo-Skymed (CSK), ERS-1, ERS-2, ENVISAT, JERS, RADARSAT-1, RADARSAT-2, Sentinel-1A (stripmap and TOPS mode), TerraSAR-X, UAVSAR
- Unix/Linux build environment requires
  - gcc 4.7+, python 3.3+, numpy, matplotlib, scipy, fftw-3.2, scons-2.0.1, gdal-2.0
  - spiceypy (optional for RadarSAT-1 only)
  - motif (optional for mdx visualization)
  - hdf5 (CSK only)

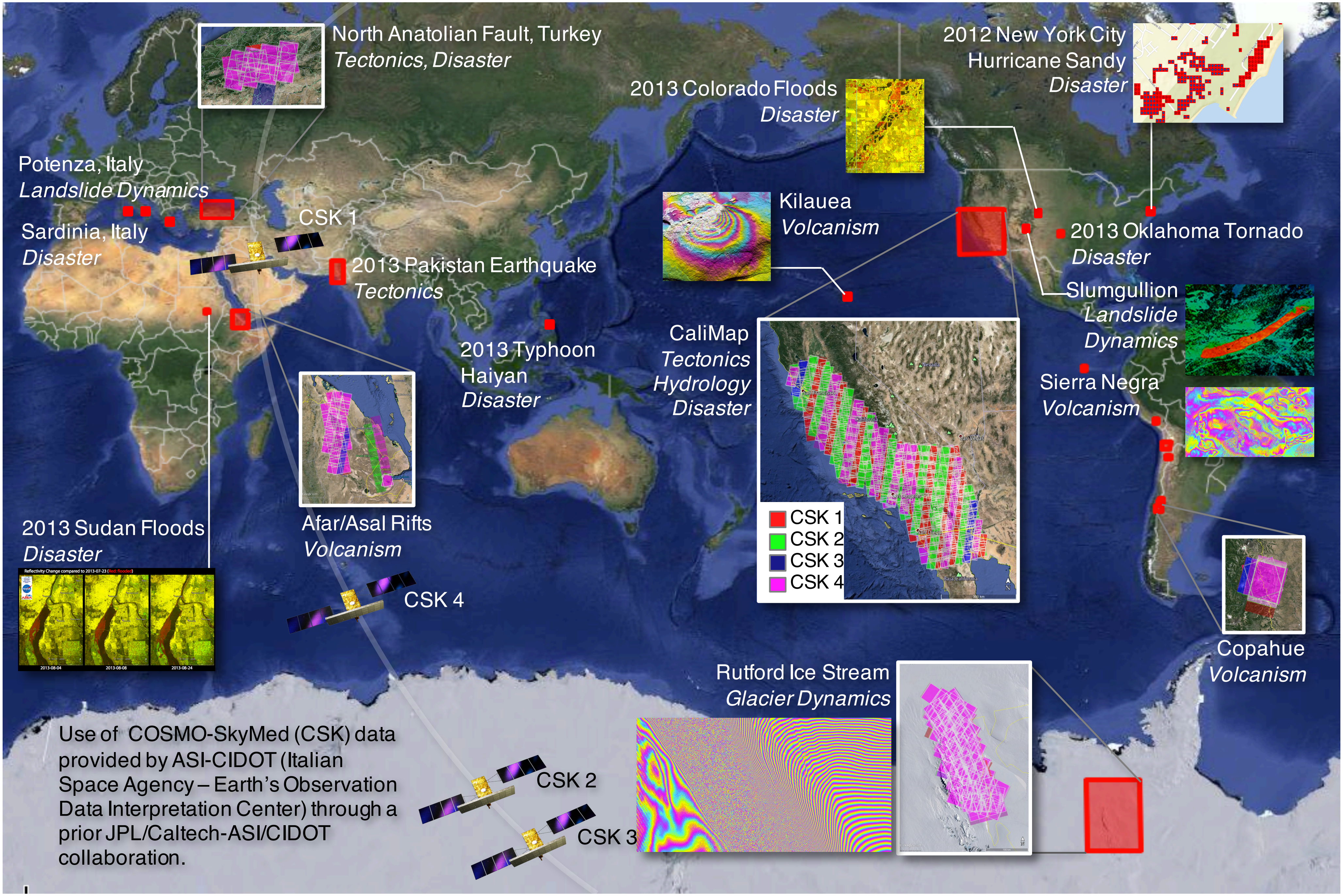
Code Availability and Community Support

- UNAVCO is licensed to distribute the ISCE software and documentation to members of the WInSAR consortium (available with password and agreement to license terms from https://winsar.unavco.org/isce.html).
  - WInSAR members comprise a significant portion of the ISCE user base
  - WInSAR maintains a large database of InSAR raw data, as well as processing tools
  - Major releases, snapshot development releases, documentation, and tutorials are available. 1000+ downloads.
- Individual research licenses can be provided by Caltech (apply at download.jpl.nasa.gov)
- Community support includes,
  - Forum wiki for report bugs and ask for help at http://earthdef.caltech.edu/projects/isce_forum/wiki
  - Biweekly user community webex meeting led by ISCE development team
  - Annual UNAVCO workshop

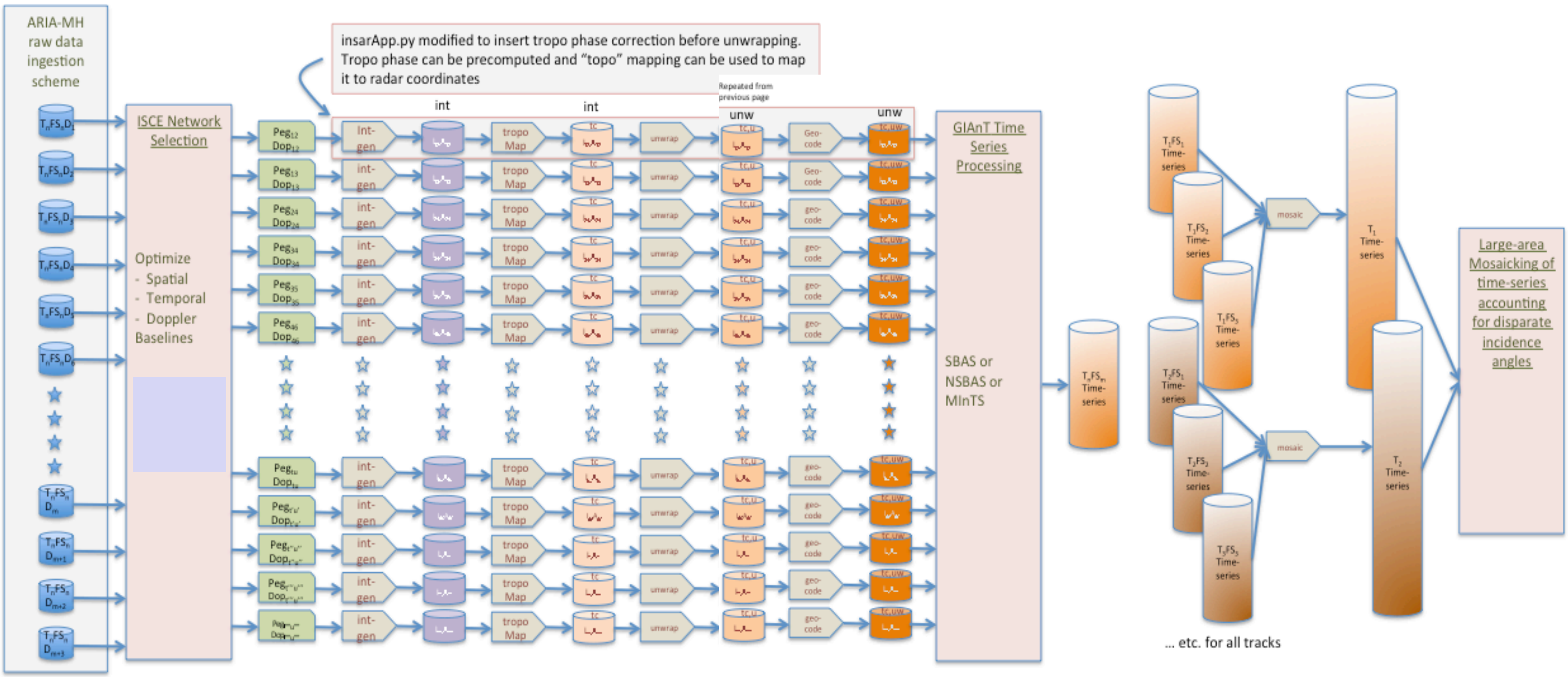
ISCE as the core of ARIA – The Advanced Rapid Imaging Analysis system



ARIA Rapid Disaster Response



Automated InSAR Processing Architecture for Large Scale Analysis



ARIA data system uses

- InSAR Scientific Computing Environment (ISCE) software
- GIAnT software for time series analysis

To generate

- Interferograms
- Tropospheric corrected interferograms
- Velocity maps

ISCE for the NASA-ISRO SAR (NISAR) Mission

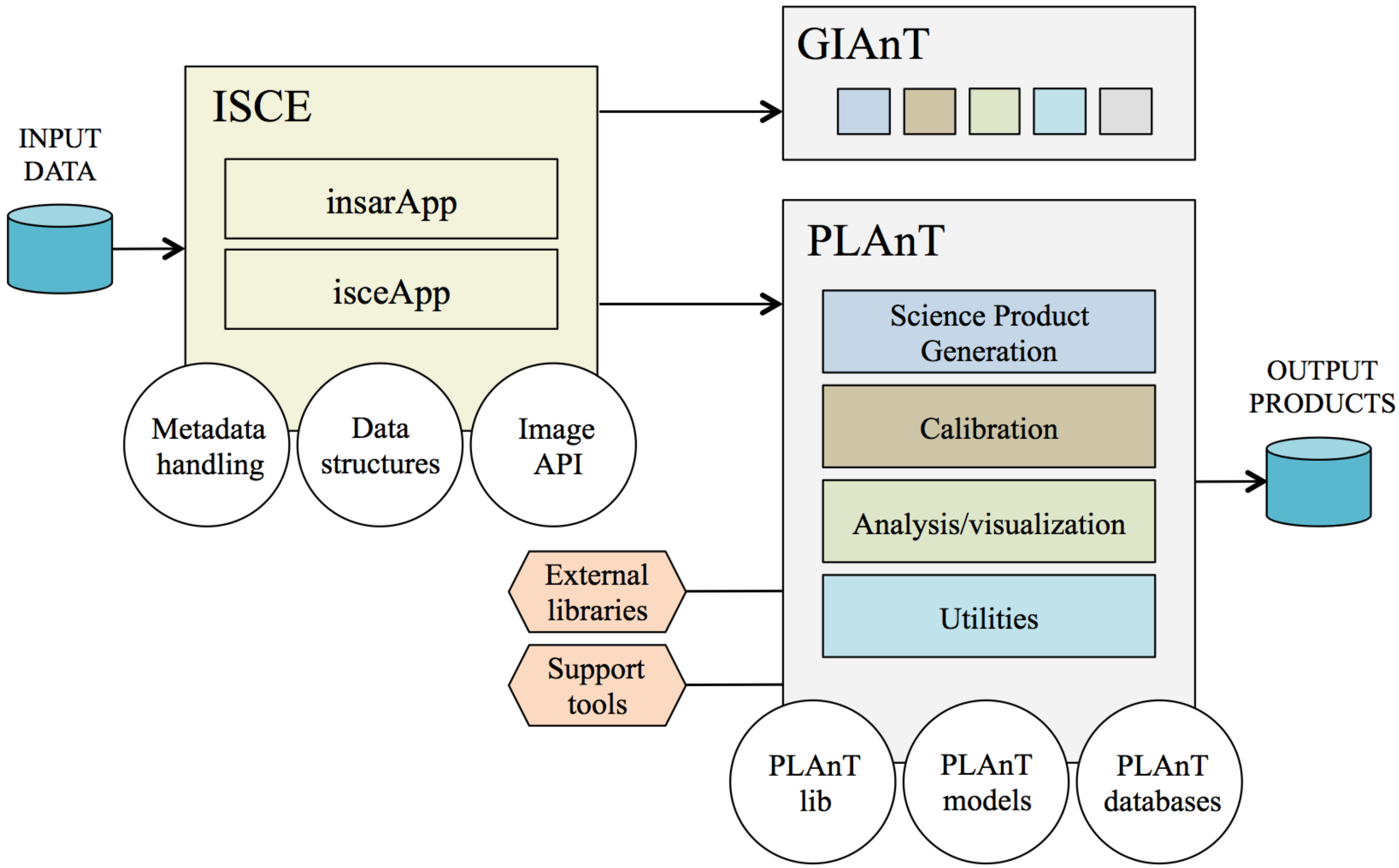
- NISAR plans to use the ARIA infrastructure for elastic computing of NISAR data to L0B (raw), L1 (Images), and L2 (interferometric and polarimetric) data levels
- ISCE will be augmented by the project to incorporate new functionality for NISAR
  - Image focusing processor for NISAR
  - Calibration/Validation tools
  - Science algorithms for biomass, deformation, time-series analysis, and mosaicking
  - Integrated tutorials and training modules
- This functionality will be available to individual scientists on their local computing devices or through cloud services

Onboarding PLAnT: Polarimetric-interferometric Lab and Analysis Tools

- The goal of PLAnT is to provide a set of tools to support processing and analysis of SAR data from Level-0/1 to Level-2/3, specifically for ecosystem and Land-Cover/ Land-Use (LCLUC) applications
- Based on ISCE components, data model, and functions
  - PLAnT provides many enhancements to ISCE MDX data visualization tools
- Integration with GDAL
  - hundreds of file formats (TIFF, GeoTiff, ENVI, CEOS, NetCDF, HDF5, ..)
  - projection changing, resampling, mosaicking, ..
- Integration with PolSARPro
  - the most comprehensive open-source software suite for analyzing and processing polarimetric SAR data

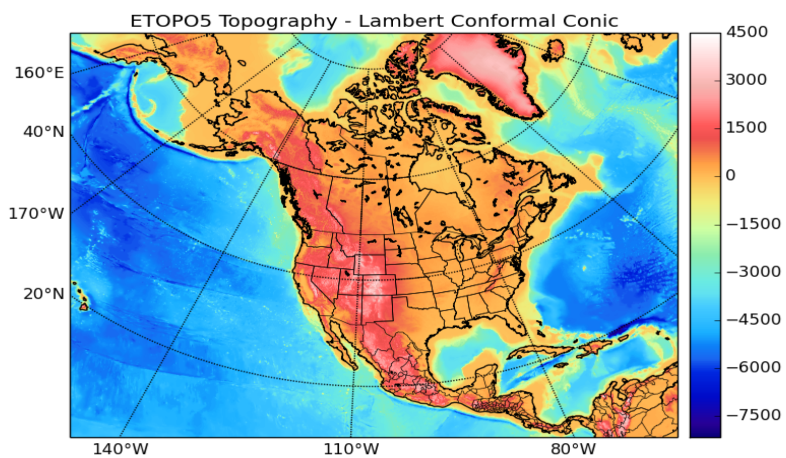
ISCE as the Front End of Workflows with PLAnT Framework (and GIAnT)

Workflows form external input data through ISCE to PLANT and GIAnT (Generic InSAR Analysis Toolbox [used by deformation community])

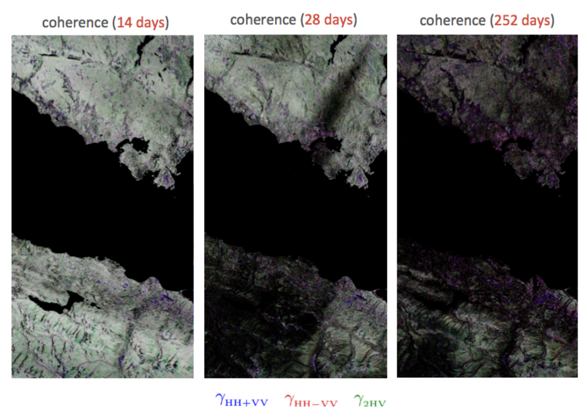


Improved mdx Visualization Tools:
fedback into ISCE from PLAnT development

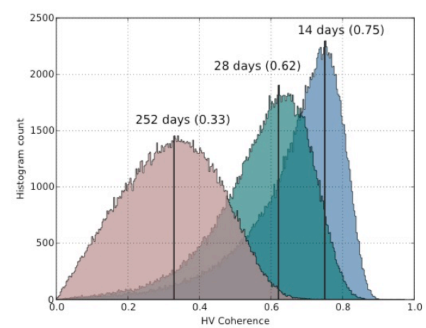
- New analysis and plotting functionalities: RGB, histogram, x- and y-profiles , scatter plot, multi-plot, image viewer.
  - Integration with matplotlib (includes geographic options from Basemap) and Tkviewer
- Supports ISCE data and non-ISCE file format supported by GDAL (Geodetic Data Abstraction Library, gdal.org)



Plot data on a geographic map through integration with matlab basemap package



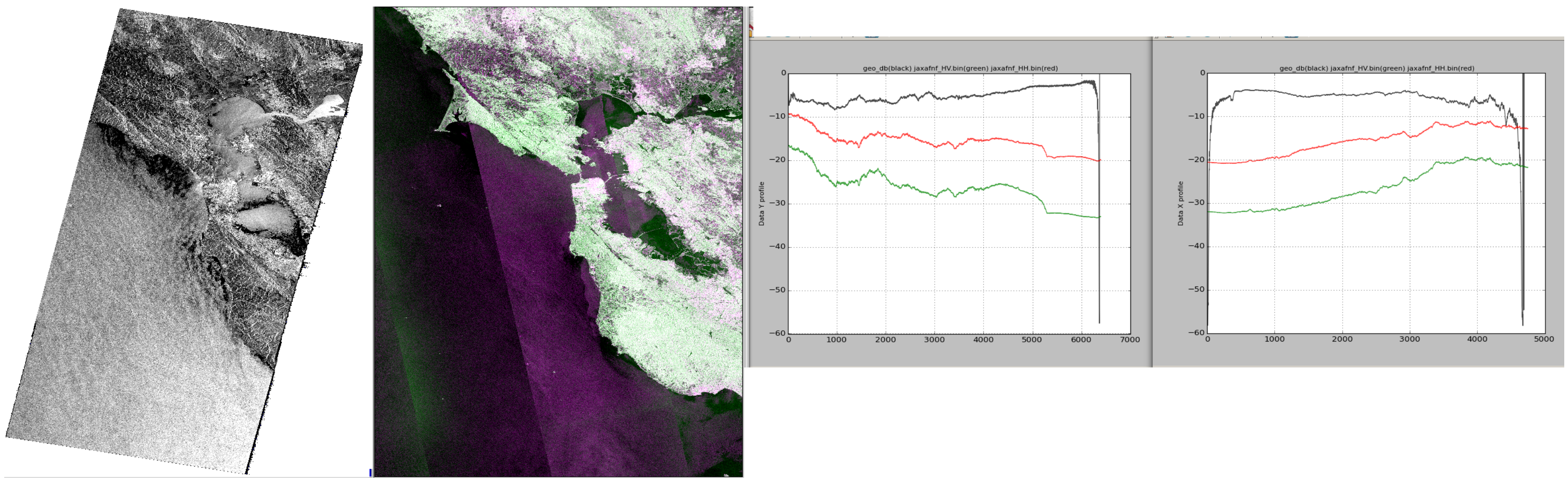
Normal mdx display of interferometric coherence files

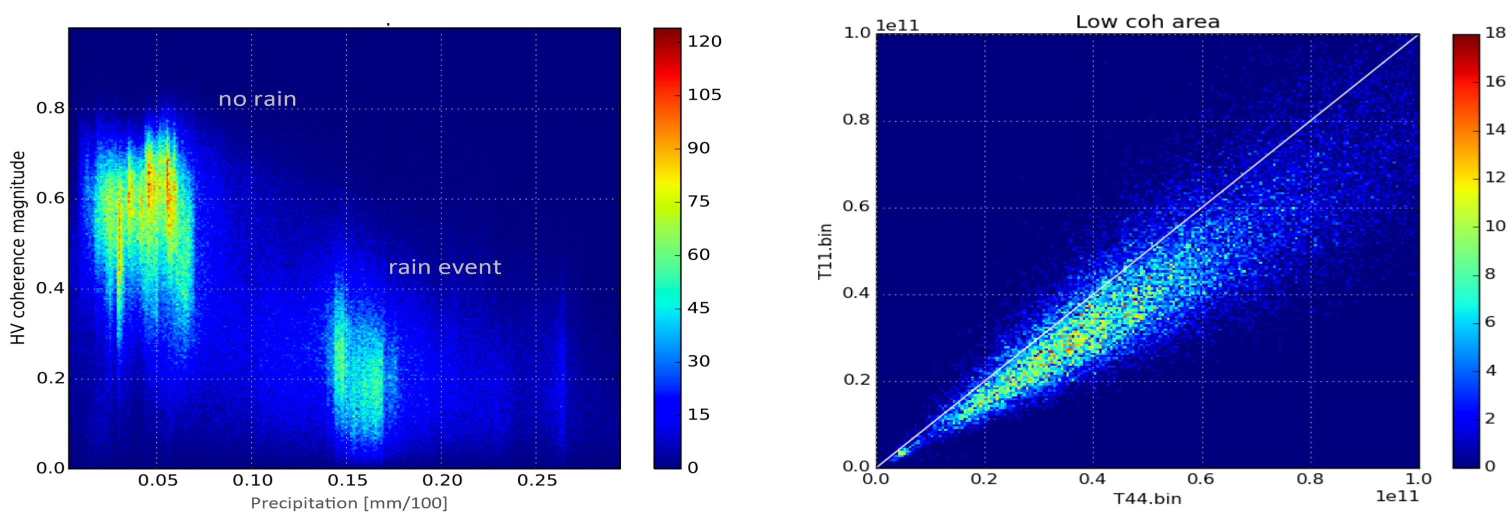


Integrated histogram analysis with matlab integration

Improved mdx visualization tool examples

- X- and Y- profiles: Sentinel-1A (C-VV: black) vs ALOS-2 (L-HH: red, L-HV: green) [dB]

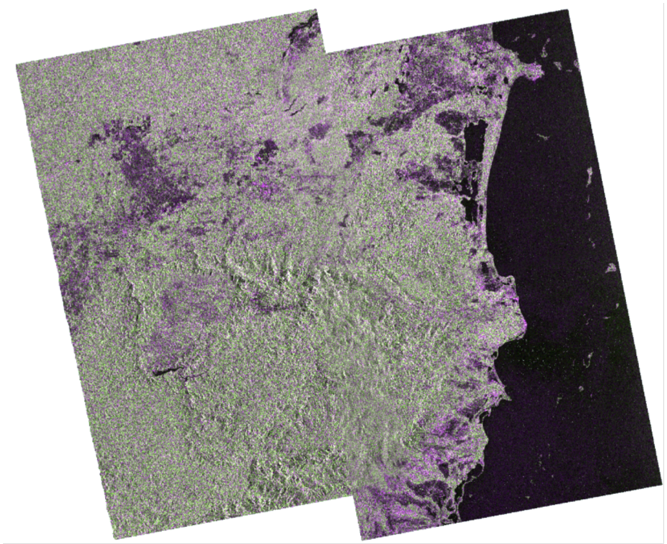




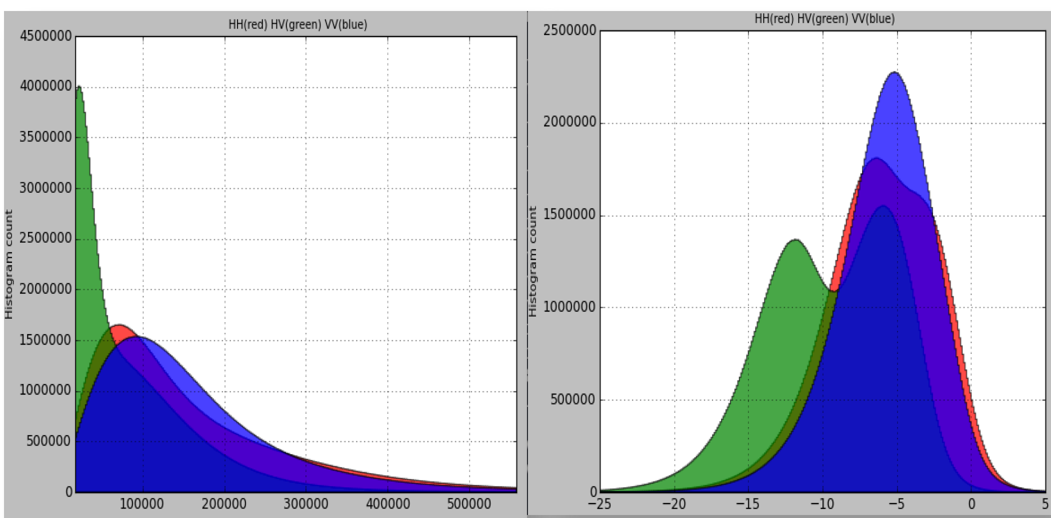
Scatter plot of ALOS-2 HV coherence vs. 8h NEXRAD accumulations (left) and T11 vs. T44 covariance matrices (Pauli decomp.) in areas affected by rain (right) near the Olympic National Park (USA)

PLAnT Analysis and Visualization Tools:

A Comprehensive Tool



- **Integrated mosaicking with GDAL**
- Inputs: ISCE or any GDAL supported file format
- Output geometry options: Bounding box and step, Reference datum,
- Can also be used for: Resampling; Coordinate system transformations; Geocoding slant-range files (if geolocation files are provided); Converting non-ISCE files to ISCE data format.

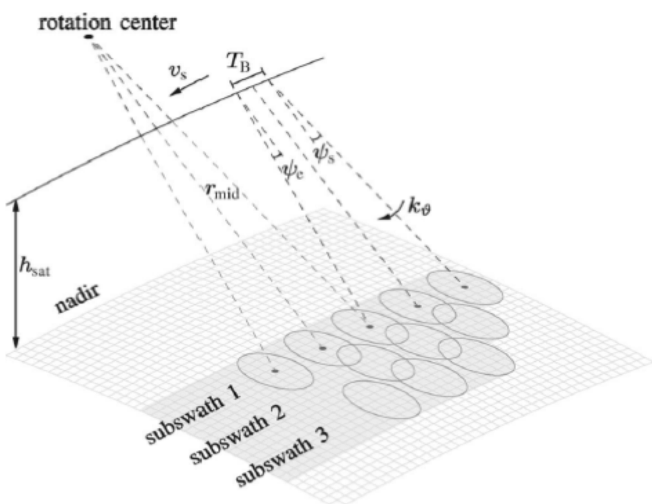


- **Absolute Radiometric Calibration**
- Plots of Histograms of ALOS-2 polarimetric backscatter before (left) and after (right) absolute radiometric correction.
- Integrated analysis using ISCE components to obtain calibration factor (from header) is stored in the metadata.
- Abscises are respectively: digital number and intensity in dB.

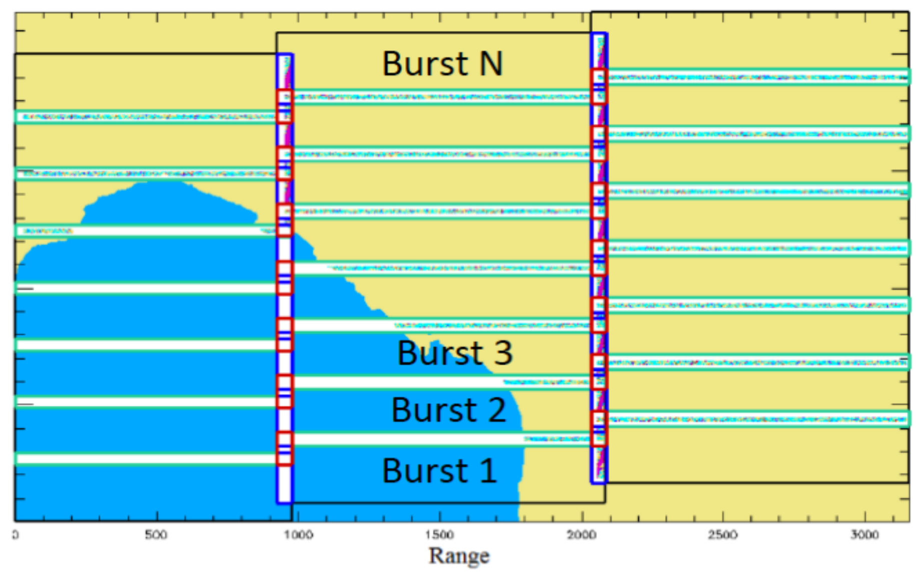
Onboarding Sentinel TOPS SAR Mode

Onboarding of new Components and Workflow for the Sentinel-1 Terrain Observation by Progressive Scans (TOPS) mode: scansar, burst-mode imaging, antenna beam scanning in azimuth.

TOPS



[Prats-Iraola et al, 2012]



Swath1 Swath2 Swath3

[Sakar et al, 2015]

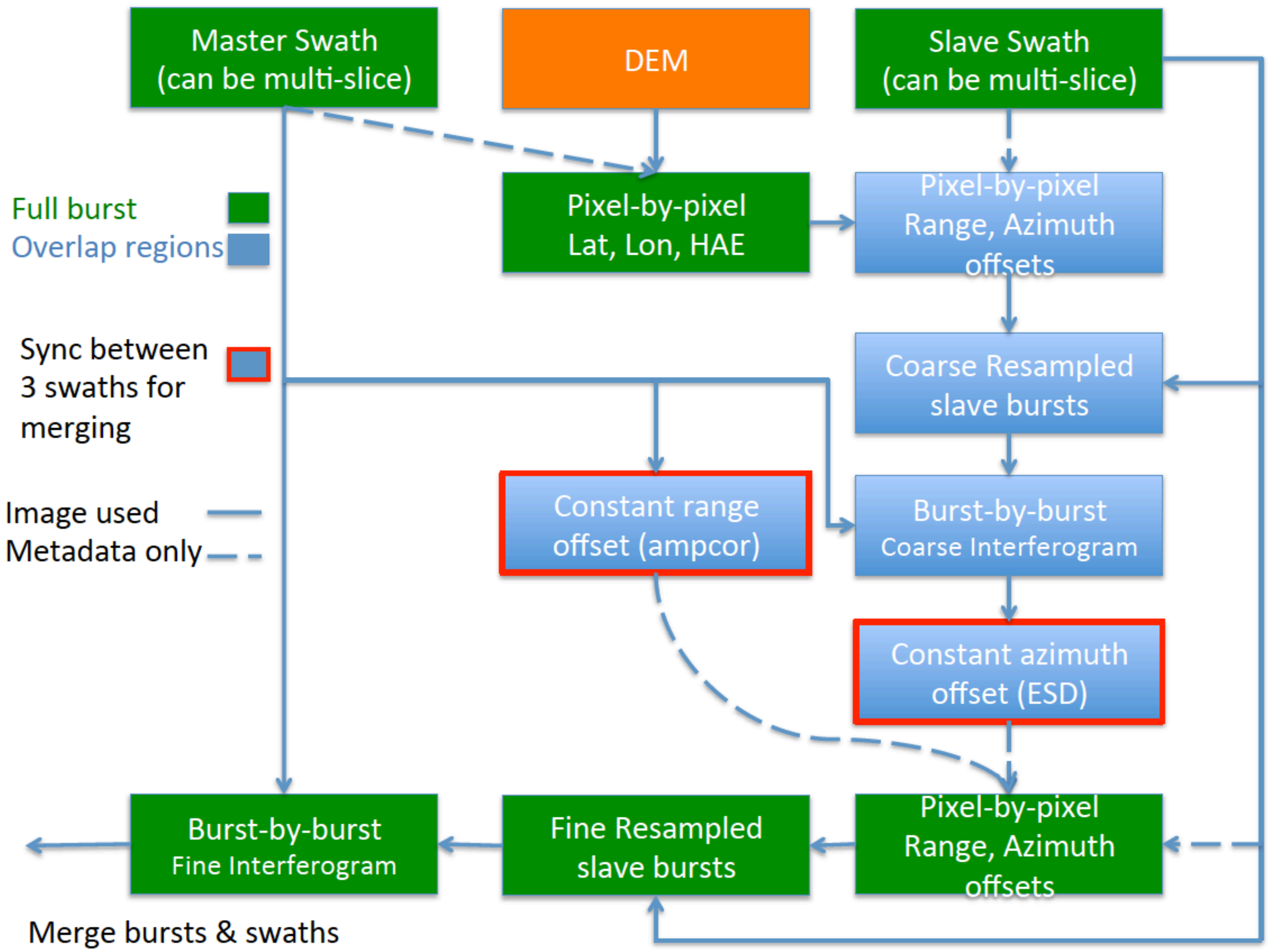
Workflow topsApp current status

- Single swath processing of S1A data
  - Multiple slice stitching (SAFE directories)
  - Cropping and processing small region of interest
- DEM-assisted coregistration
- Fine azimuth coregistration with Enhanced Spectral Diversity
- Phase corrections when SLCs are processed with different versions of IPF processor
- Merging of bursts in a swath
- Standard post processing – Filtering, unwrapping, geocoding etc.
- Mosaicking of subswaths is accomplished using GDAL, which is facilitated by the fact that every ISCE output product is GDAL compatible through a virtual raster table (vrt) metadata file.

topsApp: a Prototype for Many New Features in ISCE

- First fully productized workflow:
  - All metadata for each product are stored in XML files: human and standardly computer readable
  - Complete information for each product serialized during the flow permitting complete introspection (off line or in the flow) of the product's state and the ability to (carefully) alter the states of products and restart the workflow (or any other compatible workflow).
  - First InSAR workflow using dem-assisted coregistration for InSAR processing.
  - First workflow to use spectral diversity of two complex SAR images to detect and correct misregistration on a pixel by pixel basis that is superior to conventional methods on a sub-pixel level.

topsApp workflow



Detailed Wishlist for S1A TOPS processing

Detailed but incomplete wishlist for S1A TOPS processing

Feature	Status	Comment
Multi-slice stitching	Implemented	Users can provide multiple SAFE directories at input for stitching
Cropping with region of interest	Implemented	User can provide region of interest as a lat/lon bounding box
Dem-assisted coregistration	Implemented	Generalized for both zero doppler and native doppler geometries. Parallelized with openMP
ESD-based fine azimuth coregistration	Implemented	Estimates fine offsets using burst overlap interferograms
Merging of bursts	Implemented	Currently for a single swath
Single-swath processing	Implemented	topsApp.py processes single swath
Multi-swath processing	Planned	Will be included at a future date
EAP corrections	Implemented	https://sentinel.esa.int/documents/247904/1653440/Sentinel-1-IPF_EAP_Phase_correction

Wishlist continued ….

Feature	Status	Comment
Standard geometry layers	Implemented	Lat/Lon/Hgt/LOS (stripmap-like)
Steered LOS vectors	Planned	Overlaps are viewed from different LOS. Currently LOS vectors correspond to zero doppler geometry.
Standard post processing	Implemented	Filtering, Unwrapping, Geocoding etc
PASTA-like SLC corrections	Not planned	Rodriguez-Cassola, Marc, et al. "Doppler-related distortions in TOPS SAR images." Geoscience and Remote Sensing, IEEE Transactions on 53.1 (2015): 25-35.
Reduced disk space usage	Planned	Virtual cropping and mosaicking etc to reduce disk space usage
Polarimetric processing	Planned	Not a high priority
Optimized ESD	Implemented	Only overlap interferograms are created for ESD. Cuts processing time by 90% for generating coarse interferogram.

Vision for Future Development of ISCE

- Rapid onboarding of new Sensors and workflows through flexible, robust Component architecture and a fully productized Component model.
- The ISCE framework is being designed with flexibility and extensibility that can work in a variety of contexts ensuring support of the community at many levels
  - Individual users working on their laptop or local computing system
  - Users interacting with the cloud through VMs and staging methods for data and processor deployments
  - On-demand processing through web-based queries to a central server
  - Project-sponsored code core for production of multi-petabyte data sets

ESTO
Earth Science Technology Office

Vision for Future Development of ISCE

- Coordinated development across these levels will ensure a robust, community vetted science tool for NASA science – from ROSES to missions like NISAR

Earth Science Technology Office