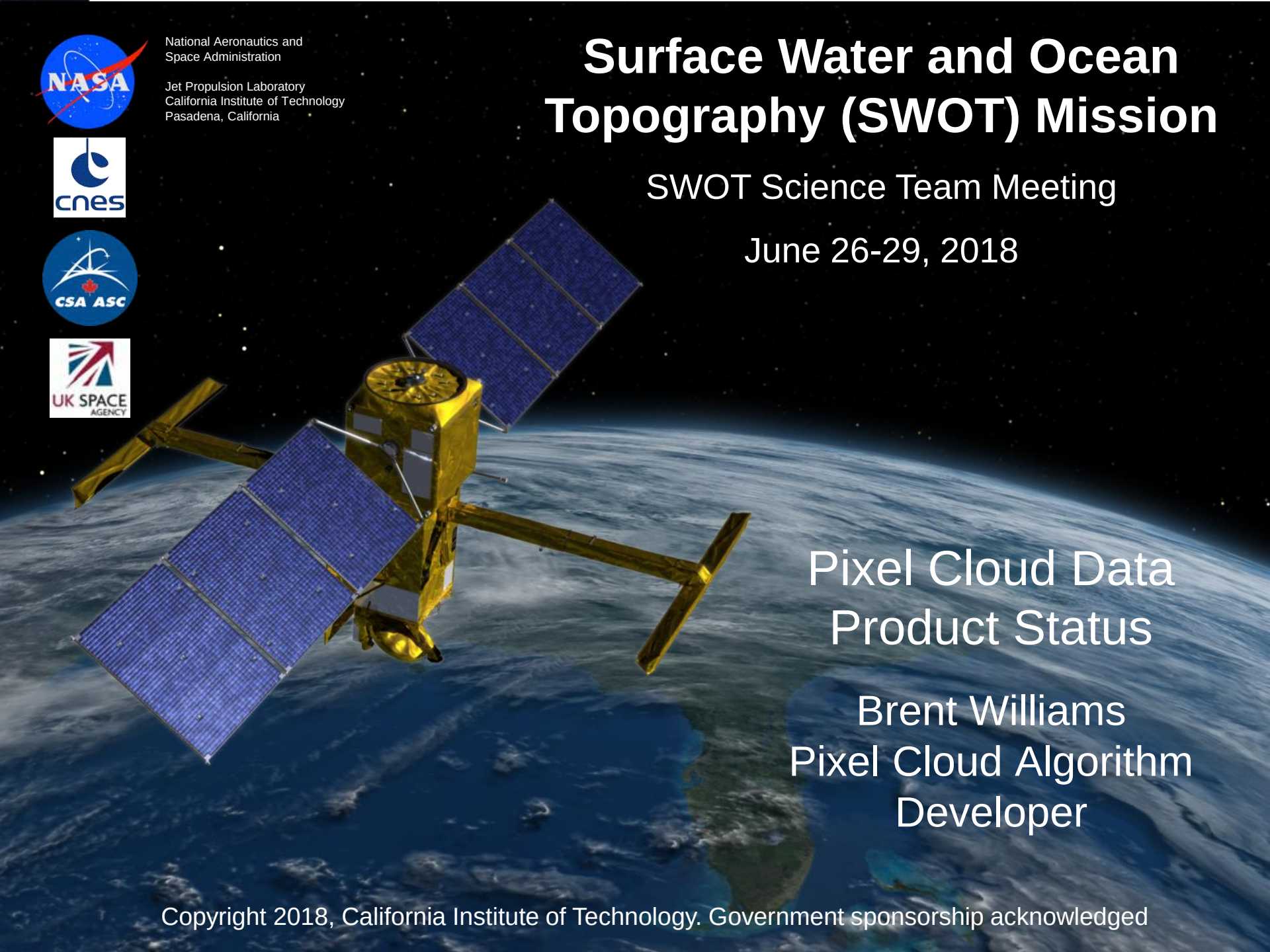


National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Surface Water and Ocean Topography (SWOT) Mission

SWOT Science Team Meeting

June 26-29, 2018

Pixel Cloud Data Product Status

Brent Williams
Pixel Cloud Algorithm Developer

Overview

- The pixel cloud product
- High level flow diagram
- PIXC and PIXC_VEC products
- Intended users
- Detailed flow diagram
- SLC to Pixel Cloud examples
- Maturity and future developments
- Uncertainty estimates
- Conclusion

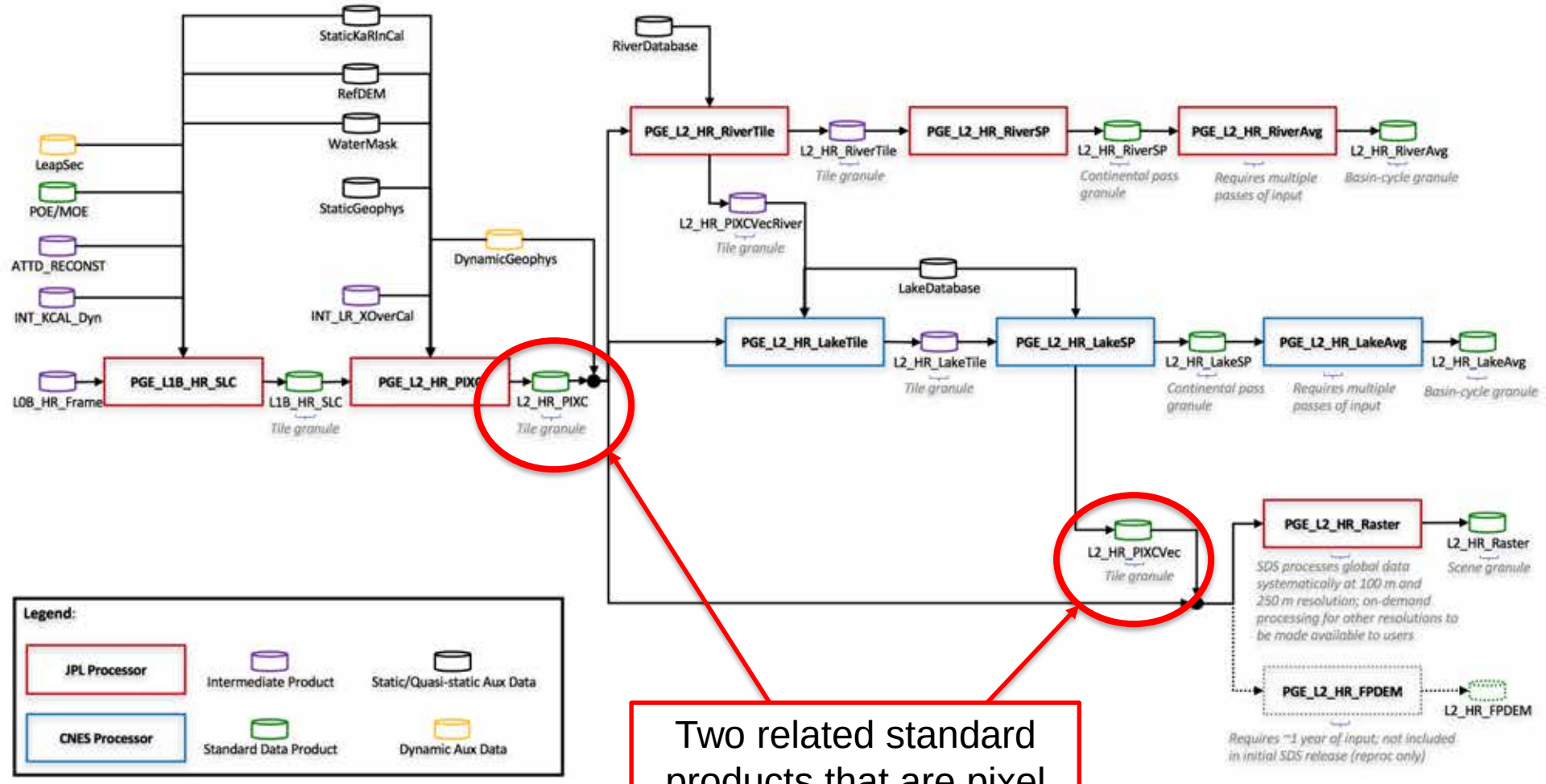
Pixel Cloud Product (L2_HR_PIXC)

- Many things in the PIXC product
  - Sensor info. (position, attitude, time…)
  - Pixel cloud info. (1-D list of radar image pixels near water)
    - Measured position of each water pixel (lat/lon/height)
    - Classification flags and water fraction estimates
    - Rare interferogram
    - Uncertainty estimates and info needed to aggregate them
    - Height corrections and references
    - Radiometric calibration, noise power and sigma0
    - Illumination time
  - Meta data (tile, pass, side…)

- Lowest level of SWOT HR data distributed in full

- Philosophy is to keep everything needed to redo geolocation and recompute much of the medium layer from rare with offline expert/experimental processing

KaRIn HR Flow



Two related standard products that are pixel clouds

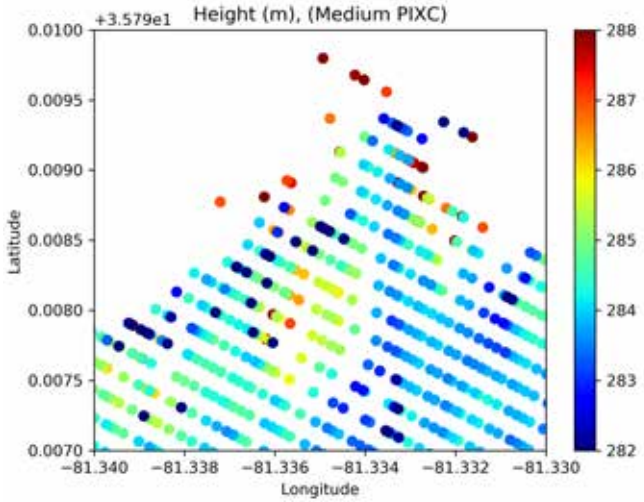
The PIXC Standard Products

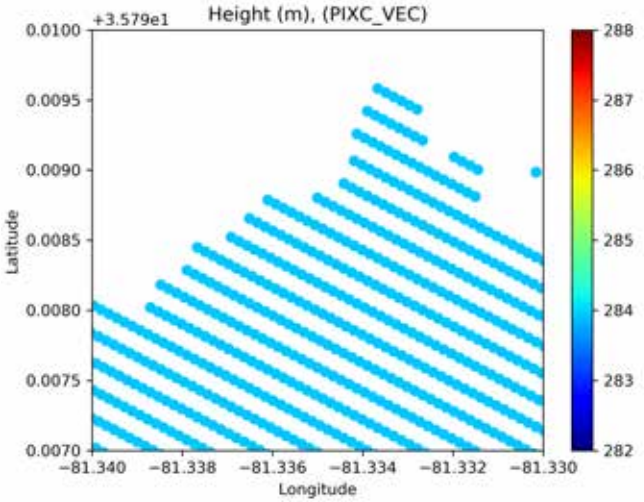
L2_HR_PIXC

- Main PIXC product with1-D list of geolocated radar image grid pixels around water (detected and prior)
- Rare-level interferogram information (4 effective looks)
- Medium-level (~50 looks) geolocated lat/lon/heights and uncertainty estimates
- Water detection and flagging results
- Calibration and sensor info.
- Height references and corrections (included but not applied)

L2_HR_PIXC_VEC

- Ancillary/overlay product contains info. not available until after river and lake vector level processing
- IDs for each pixel that was attributed to any feature (node, reach, lake, unknown …)
- Height constrained geolocation using aggregated heights at the water feature level (i.e., lat/lon/height for well-done-level of smoothing)

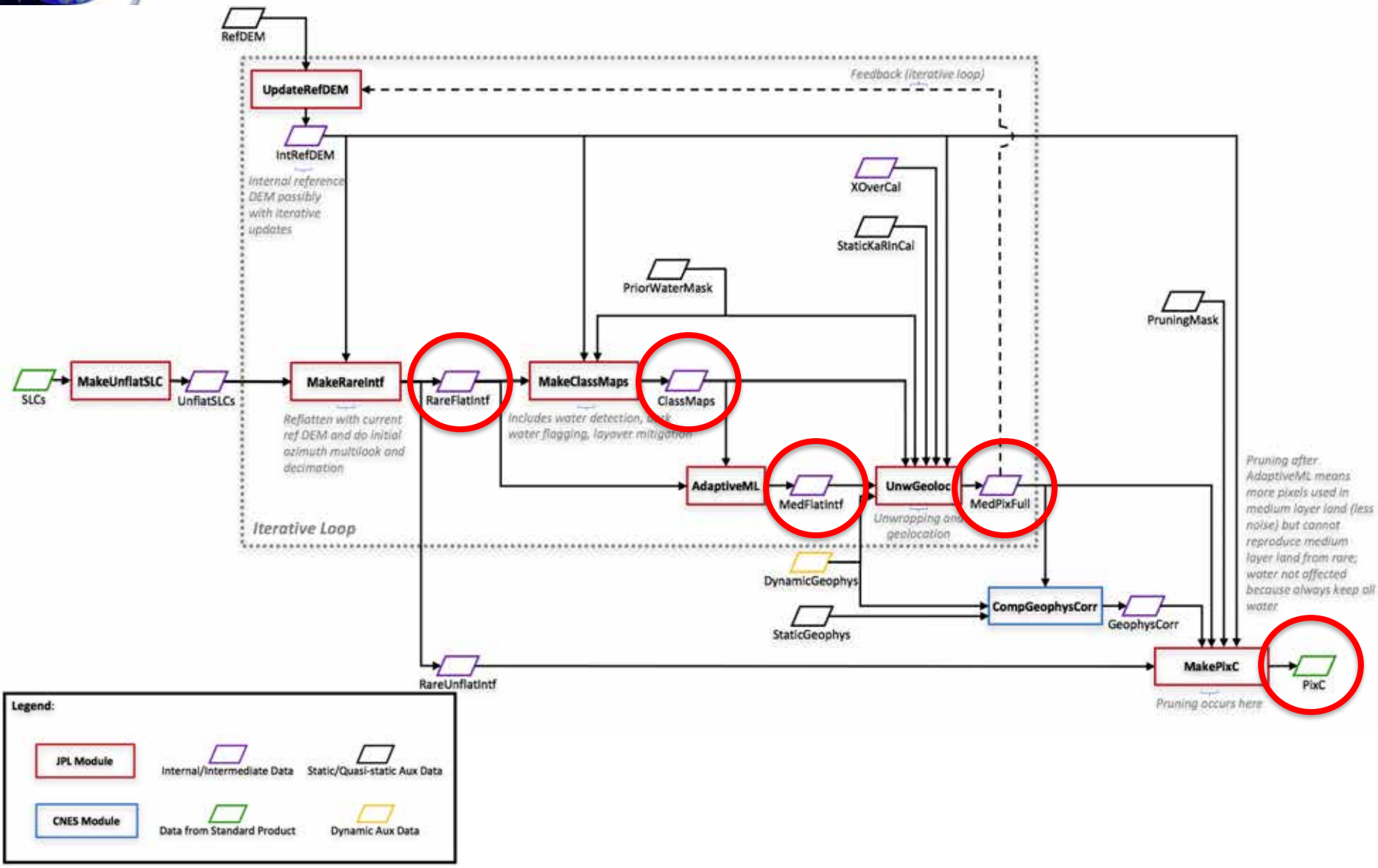




Intended Users

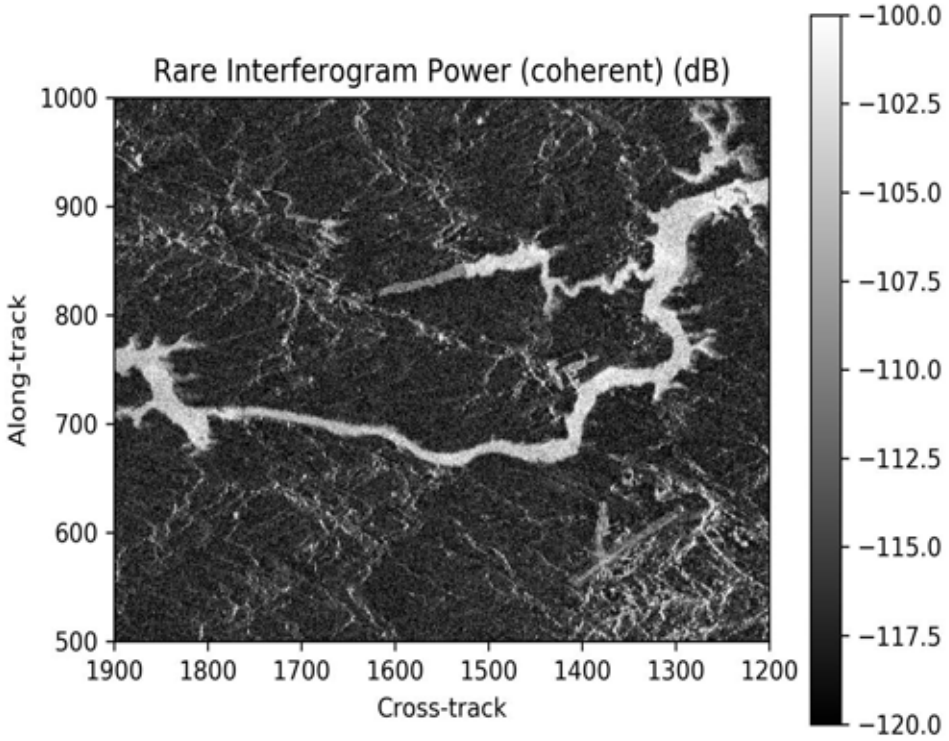
- PIXC and PIXC_VEC are expert products, intended users are:
  - Hydrologists interested in studying fine-scale details in a local region
    - Higher spatial resolution, but noisier than vector products
  - Users interested in low level data for calibration/validation and downstream algorithm development
  - Possibly other applications
    - Lowest level of data available in whole
    - Studies like Ka-band scattering, rain, ice/snow, soil moisture, urban sprawl, inland water body wind vector/wave height estimation etc…
- The “raster” product can also serve most/many hydrology users that need finer scale measurements than the vector product, but don’t need detail and additional complexity of the pixel cloud

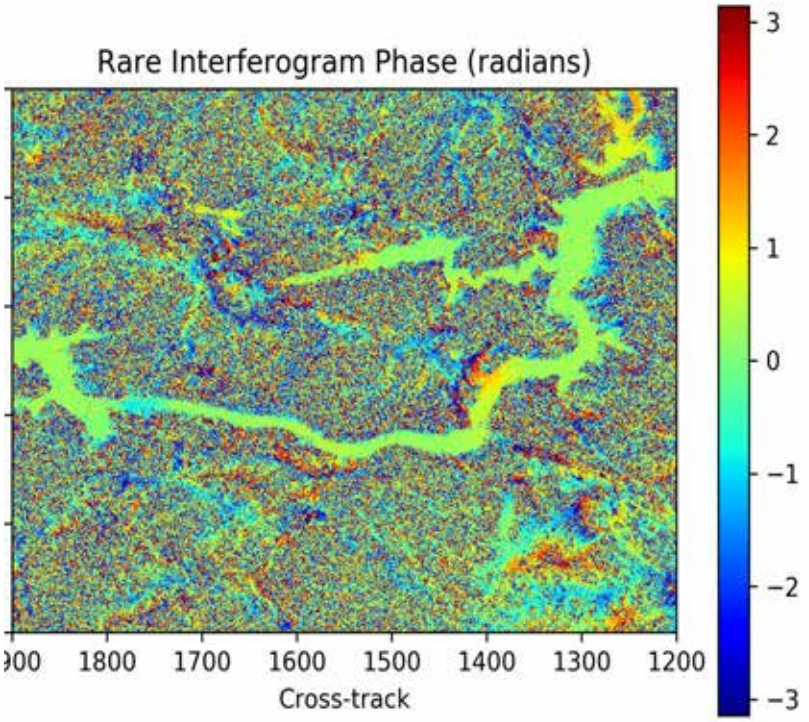
Pixel Cloud Processor Top Level Flow



Rare Interferogram

- SLC images are interfered and multi-looked (~spatially averaged)

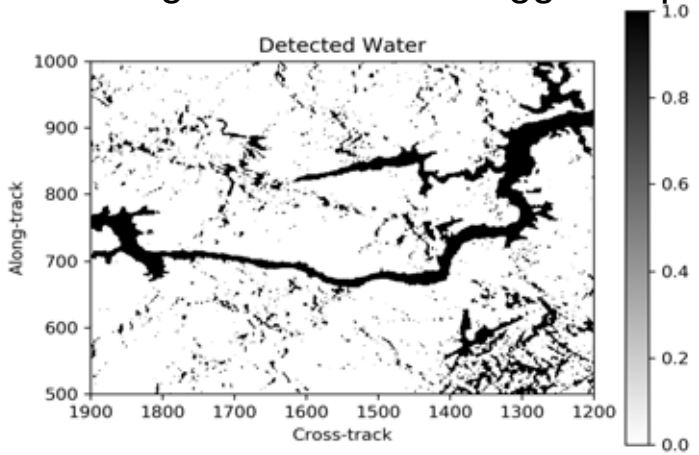


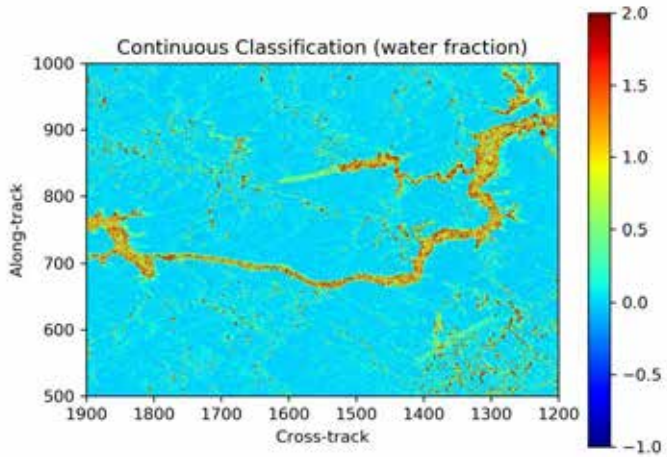


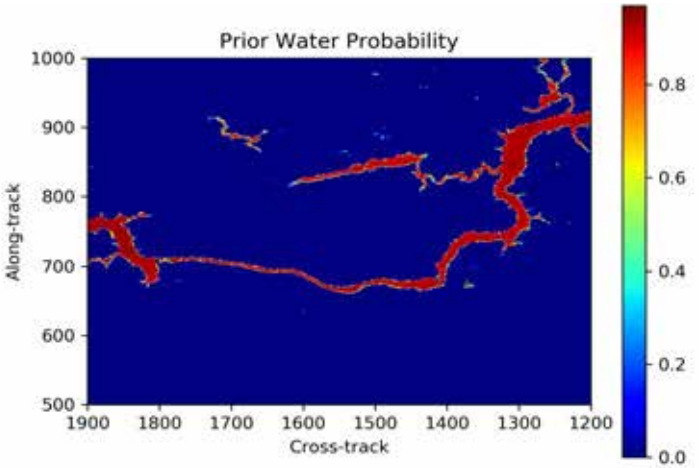
Lake Hickory,
North Carolina

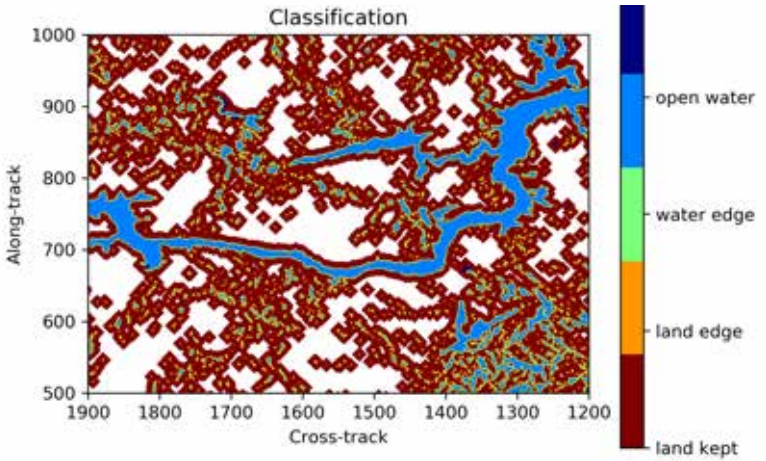
Water Detection

- Power threshold-based binary detection with MRF spatial regularization
- Fractional water estimation
- Dark water flagging base on prior water mask
- Edges/boundaries flagged separately



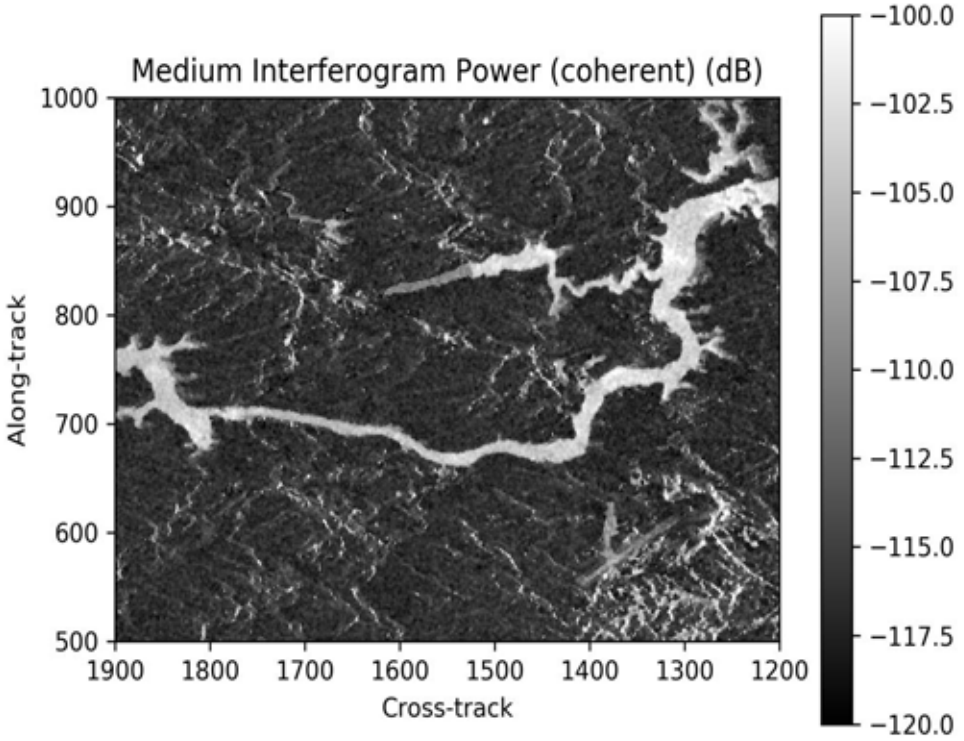


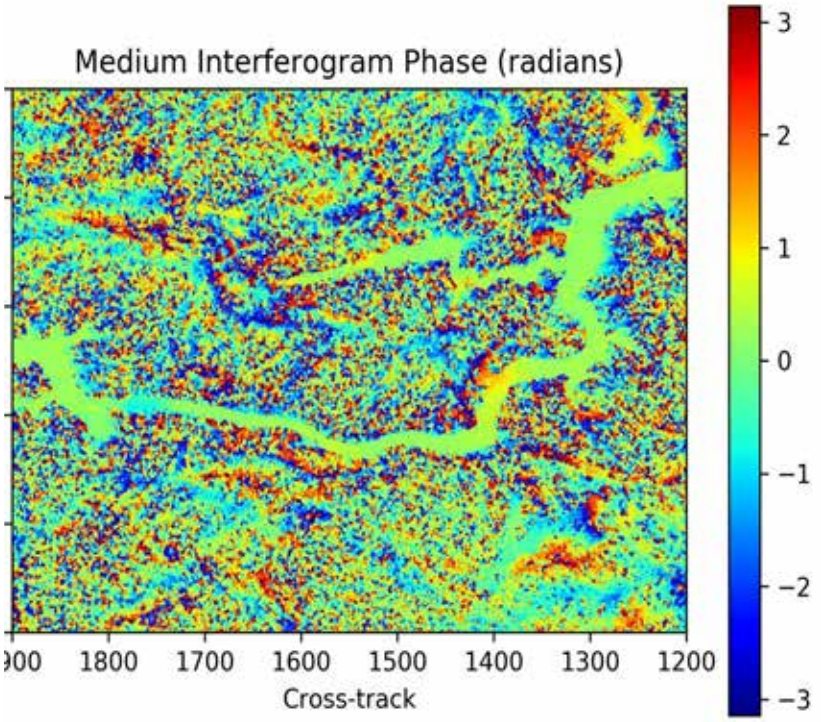




Medium Interferogram

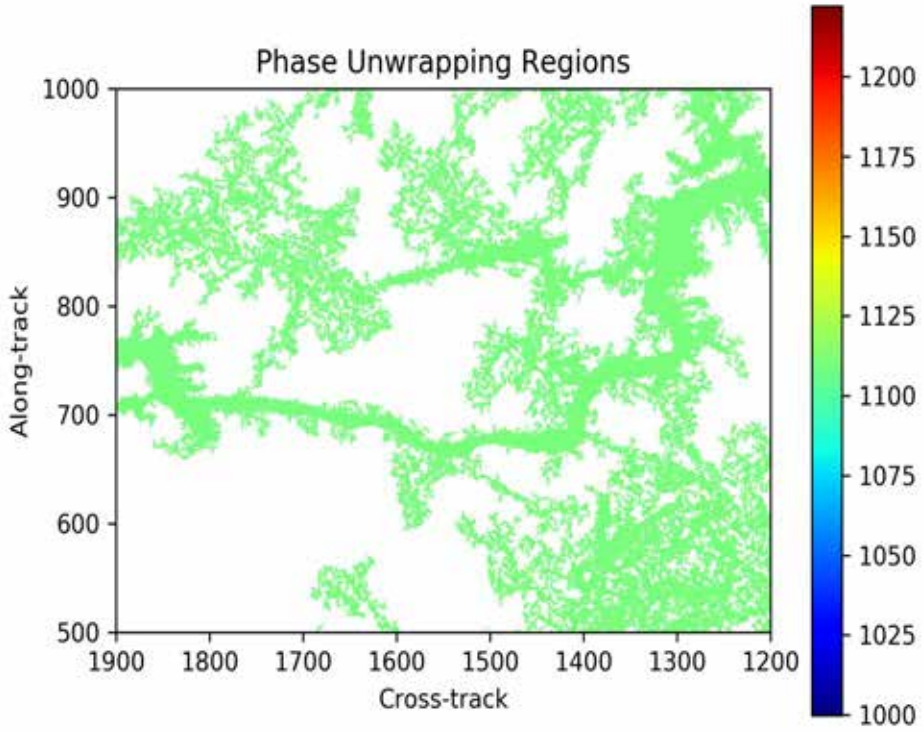
- Interferogram adaptively multi-looked using detected classes

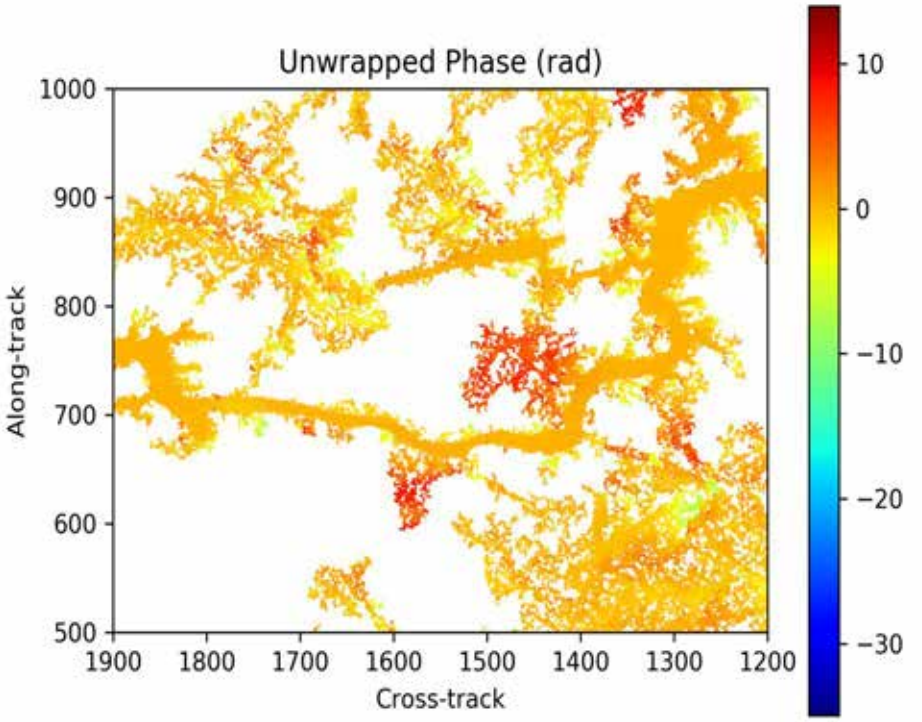




Phase Unwrapping

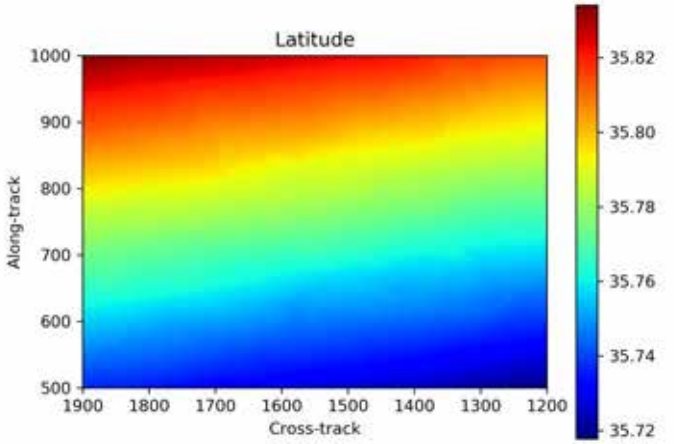
- Spatial phase unwrapping over connected regions
- Ambiguity resolution of each region (using prior DEM and water mask)

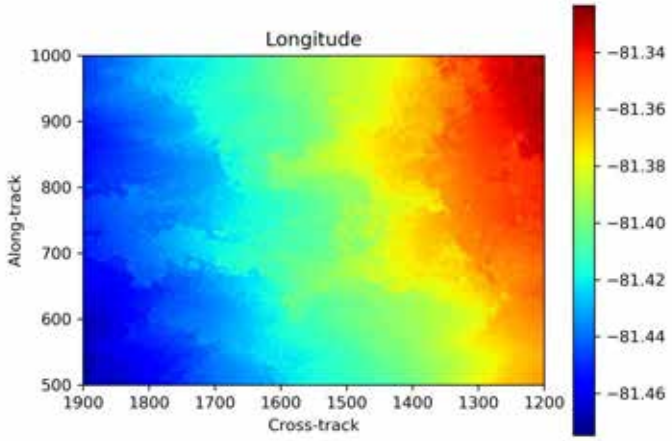


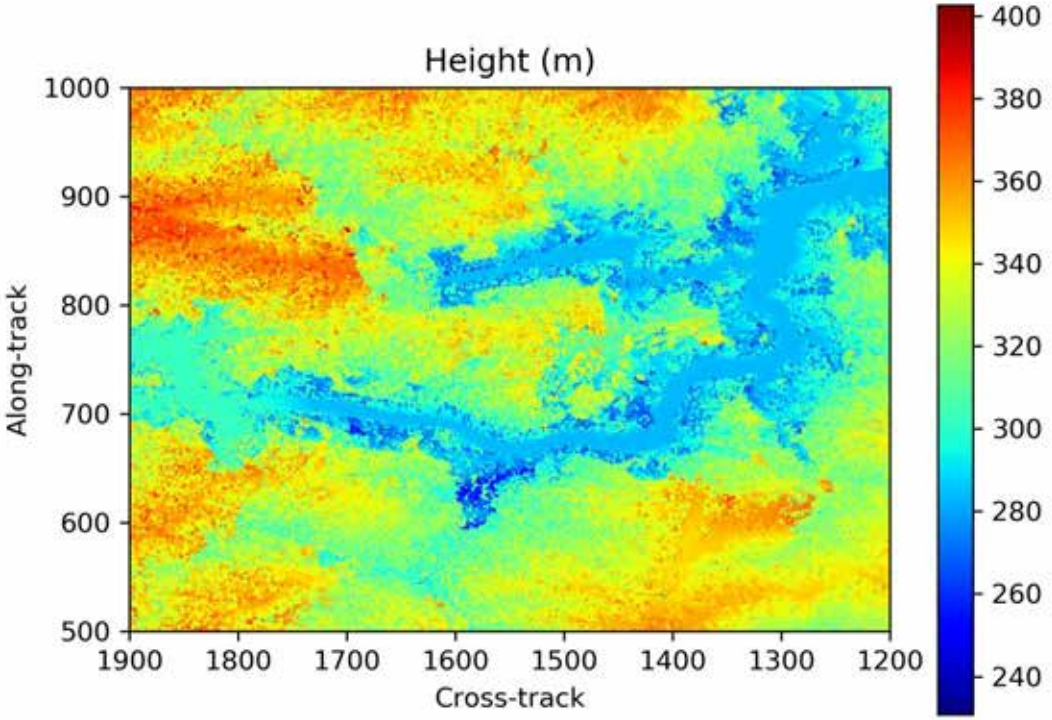


Geolocation

- Absolute phase, range, and doppler (azimuth) converted to lat, lon, height above WGS84 ellipsoid

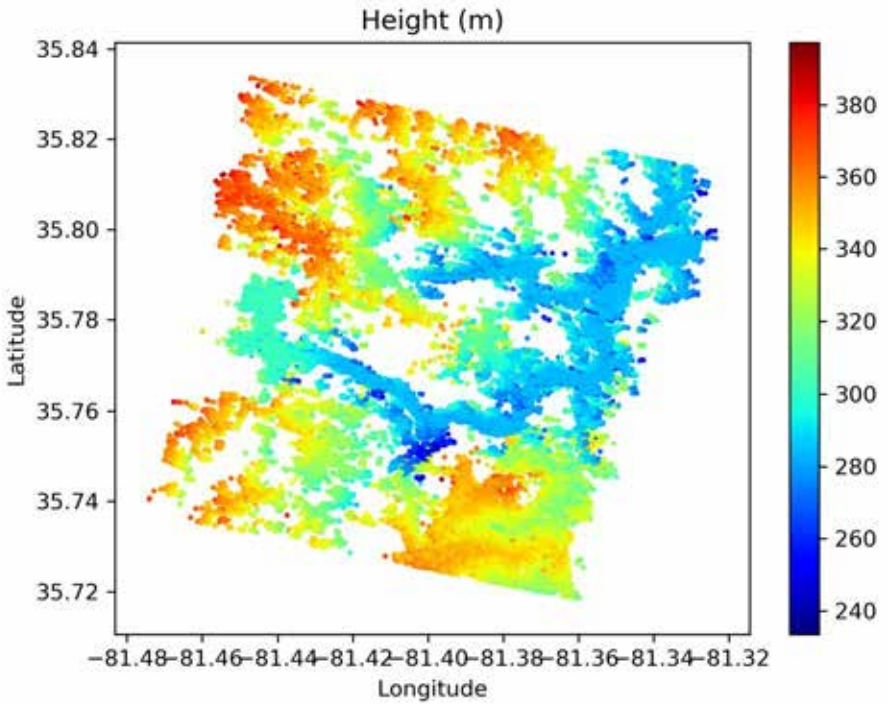


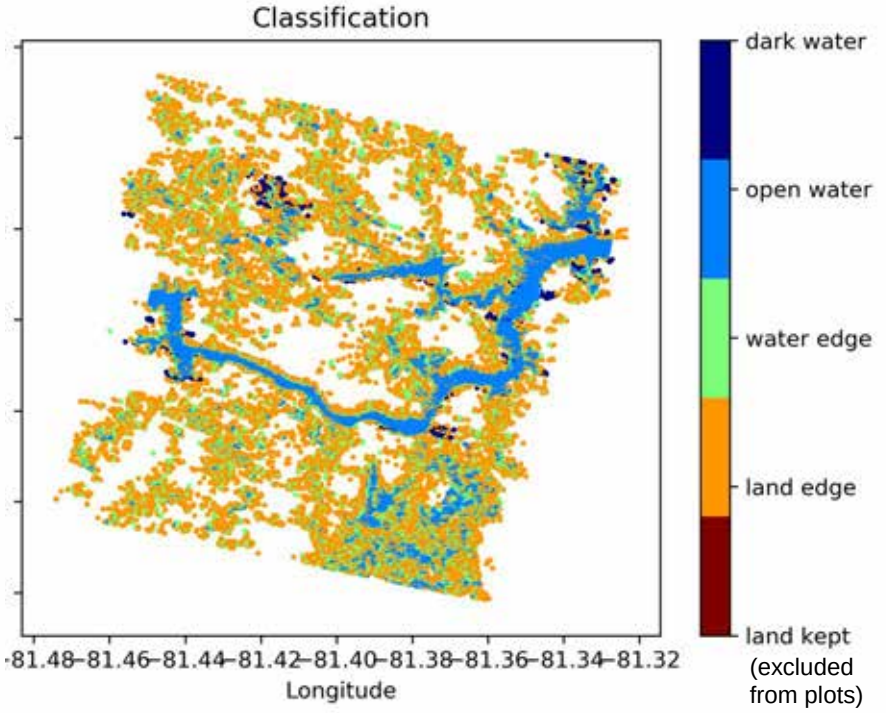




Prune and Create Pixel Cloud

- Exclude pixels not near water (or prior pruning mask)
- Reorder to 1-D list
- Include (but don't apply) height corrections, e.g., geoid, Earth tide…





Maturity and Future Developments

- Most of the major pixel cloud algorithms have been implemented in some form and the corresponding PIXC variables are populated in the output products
  - Baselines for water detection, phase unwrapping, and layover mitigation
  - Many algorithms will still be improved/upgraded
  - Details of pixel cloud product variables/fields will continue to evolve
  - Height and area uncertainty estimation being developed and assessed

- Some of the variables are not yet included (or not populated) in the current output products
  - Instrument corrections
  - Height reference corrections
    - Geoid
    - Solid earth tide
  - Wet/dry troposphere and ionosphere range correction
  - Cross-over calibration corrections
  - Phase screen

Uncertainty Estimates

- Primary hydrology measurements are the water height and area (at PIXC level)

- Uncertainties on these are also desired in all hydrology products
  - In PIXC product the uncertainties are not provided directly
  - All the info. needed to compute them is in PIXC product
  - PIXC also has all the info. needed to optimally aggregate to nodes/lakes/raster bins and estimate uncertainties of the aggregates
    - Geolocated “medium” pixels are correlated so the uncertainties after aggregation do not simply fall off as 1/sqrt(N)
    - Currently developing, implementing, and assessing methods to estimate aggregate uncertainties
    - The uncertainties are directly provided in the more aggregated hydrology products (river, lake, and raster)

Conclusion

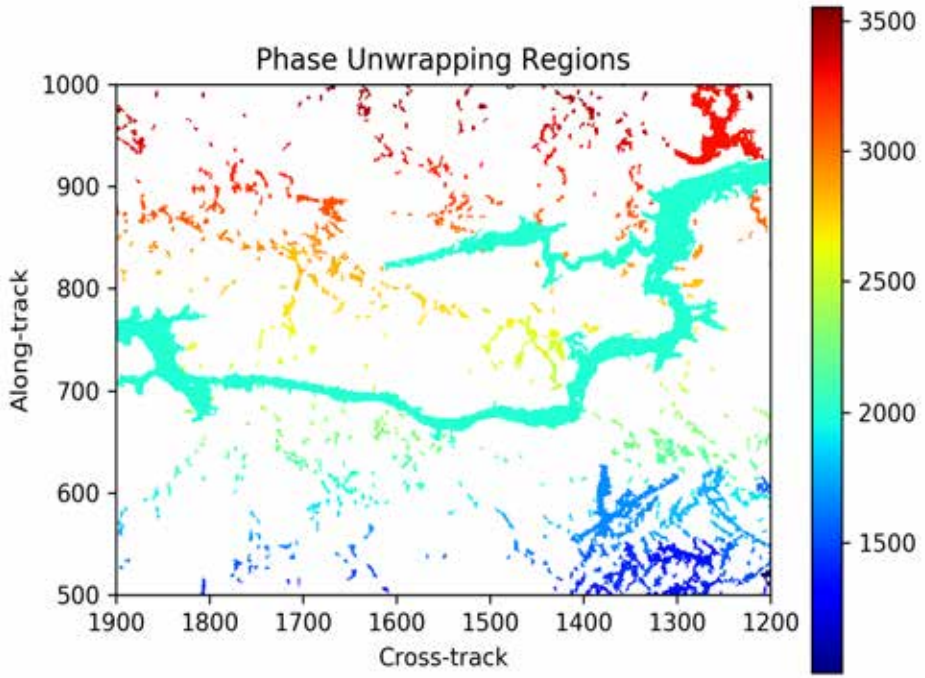
- Introduced PIXC and PIXC_VEC products
- Shown some examples of data flowing from SLC to PIXC products
- Example data products can be created by the simulators
  - Prototype processor produces current best description of the PIXC as it evolves
  - Large scale simulator likely to update periodically to match current best description of the PIXC as it evolves
  - PIXC_VEC produced by output of River-Tile processor (LOCNES)
- Details of the products are also formally tracked through periodic updates to Product Description Documents (PDDs)

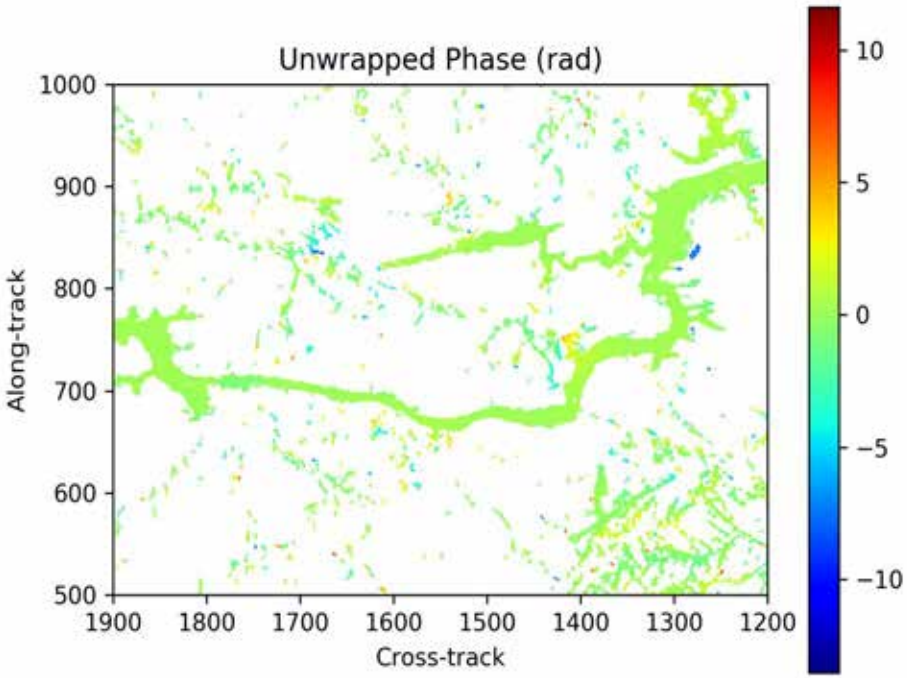
Backup

Phase Unwrapping

- Spatial phase unwrapping over connected regions
- Ambiguity resolution of each region (using prior DEM and water mask)

Coherence threshold 0.5, instead of 0.2





Detailed PIXC Variables

- Sensor (TVP) variables:
  - time
  - latitude, longitude, height (sensor/platform position)
  - roll, pitch, heading (attitude)
  - x, y, z (xyz/ECEF position)
  - vx, vy, vz (xyz velocity)
  - ref_leverarm_x, ref_leverarm_y, ref_leverarm_z (pos. of antenna 1)
  - sec_leverarm_x, sec_leverarm_y, sec_leverarm_z (pos. of antenna 2)

Detailed PIXC Variables

- Pixel cloud variables:
  - azimuth_index, range_index (slant plane indices)
  - x_factor_left, x_factor_right (radiometric calibration)
  - noise_power_left, noise_power_right (noise power measurements)
  - pixel_area
  - incidence_angle
  - classification
  - continuous_classification (water fraction estimate)
  - Ifgram (complex rare interferogram)
  - power_left, power_right, coherent_power (powers of rare interferogram)
  - num_rare_looks
  - latitude, longitude, height
  - cross_track
  - phase_noise_std, dlatitude_dphase, dlongitude_dphase, dheight_dphase (for uncertainty estimation/aggregation)
  - illumination_time
  - num_med_looks
  - sigma0 (normalized radar backscatter/brightness)
  - regions (phase unwrapping region ID)