PROTOTYPING RADIOMETRICALLY TERRAIN CORRECTED SENTINEL-1 LARGE-SCALE PROCESSING

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UAF Alaska Satellite Facility — Making remote-sensing data accessible since 1991

UAF University of Alaska Fairbanks

CEOS

CEOS SAR Cal/Val 2017, JPL

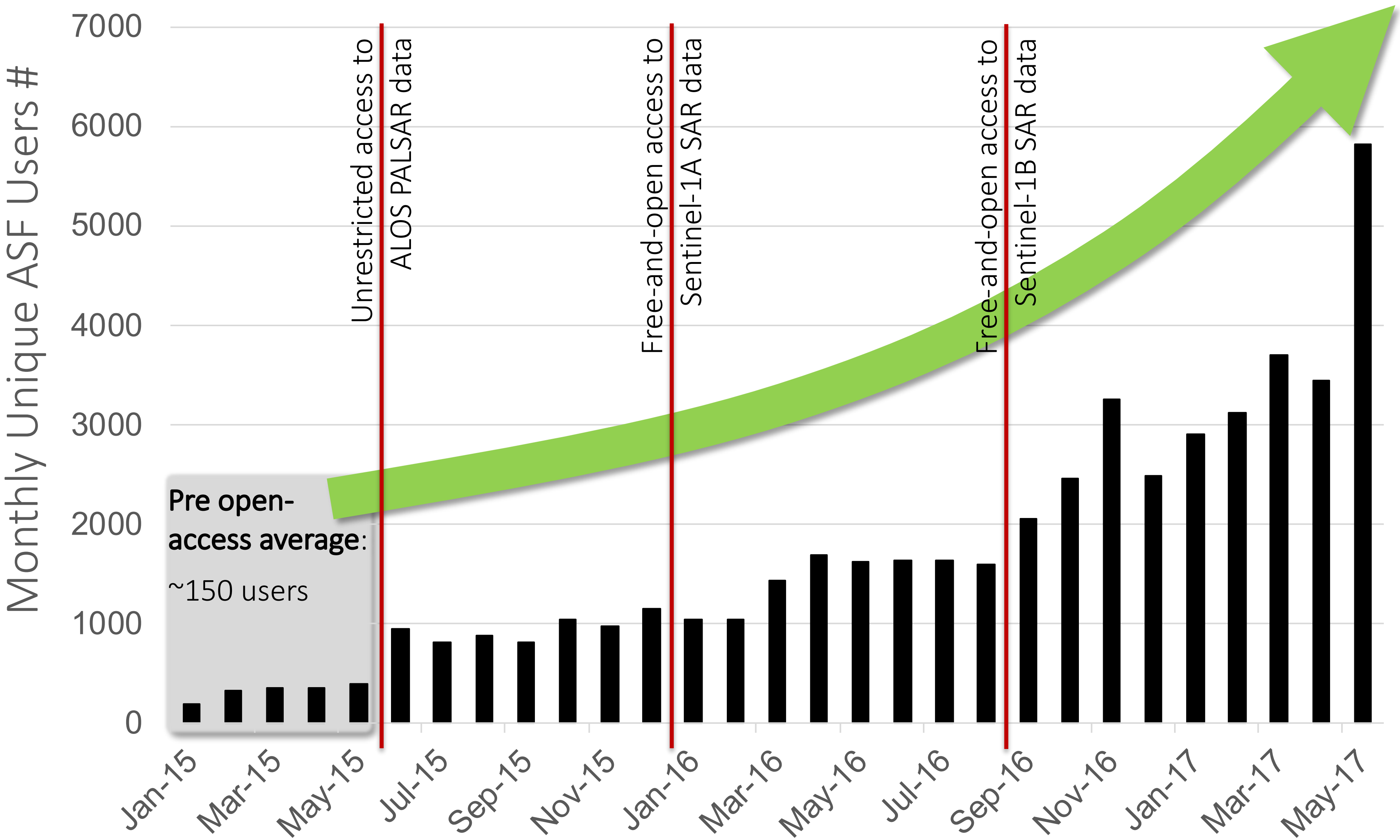
A Short Intro to the Alaska Satellite Facility (ASF)

- **ASF is NASA Distributed Active Archive Center (DAAC) for SAR Data**
  - Established in 1991 as the prime U.S. downlink and processing center for SAR data
  - Operates three antennas for command uplink and data downlink of a series of NASA and non-NASA remote sensing satellite systems

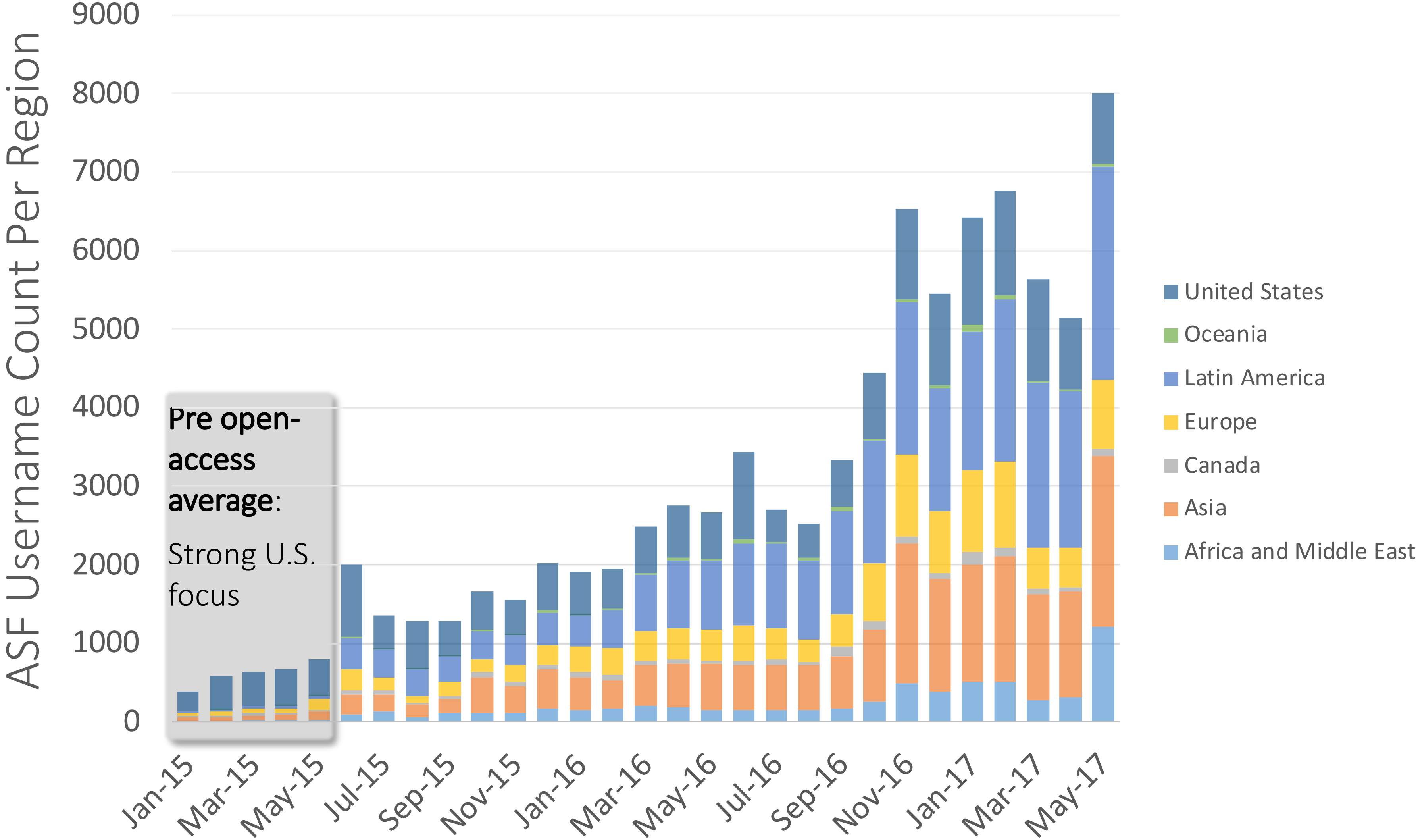
- **In Dec ’15, ASF has become one of the hosts of the complete Sentinel-1 SAR data archive**
- **Since then, ASF’s archive has grown rapidly, currently housing about 3.5PB of SAR data in its archives (all on spinning disks for immediate download)**

Visit ASF @ www.asf.alaska.edu

Free-and-Open SAR Data Has Been Changing the SAR Community



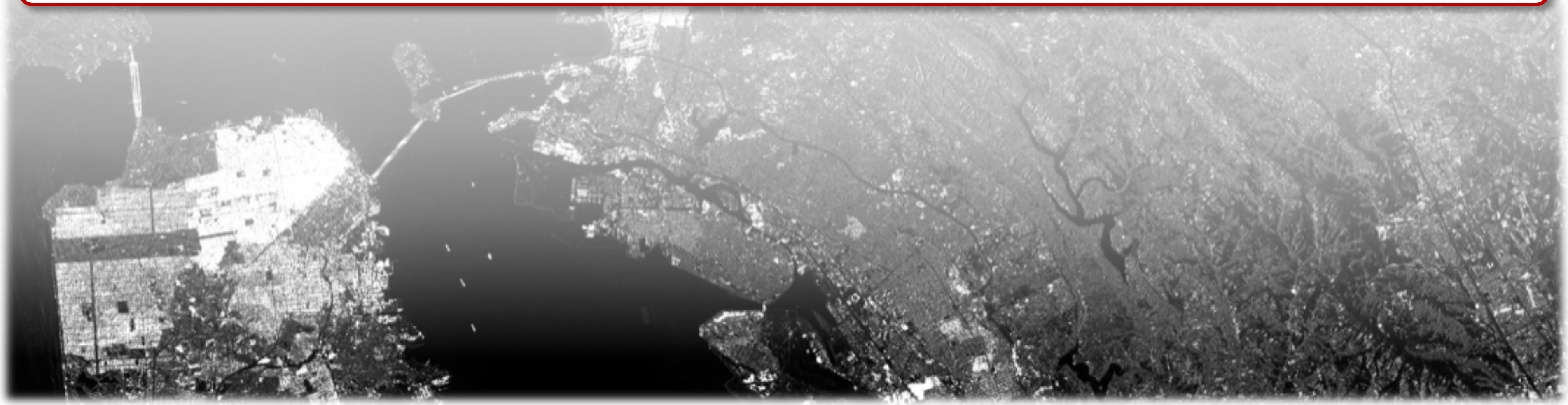
Open Data Has Diversified the SAR User Community

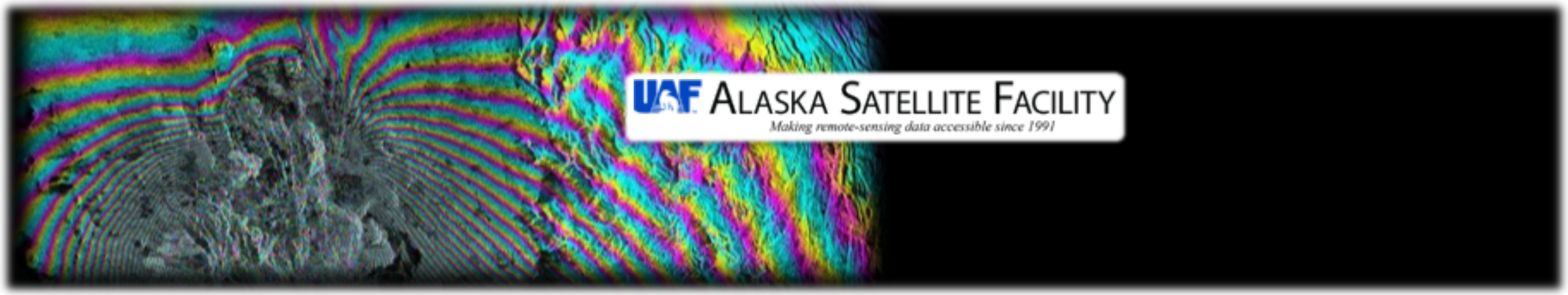


Many Non-Traditional SAR Users are Looking for Geocoded & Terrain Corrected (GIS-Ready) Data

- **Interest in GIS-ready data, that can be …**
  - Easily combined with data from other sensors
  - Seamlessly mosaicked with neighboring swaths acquired at different incidence angles
  - Lends itself for mapping & Change detection

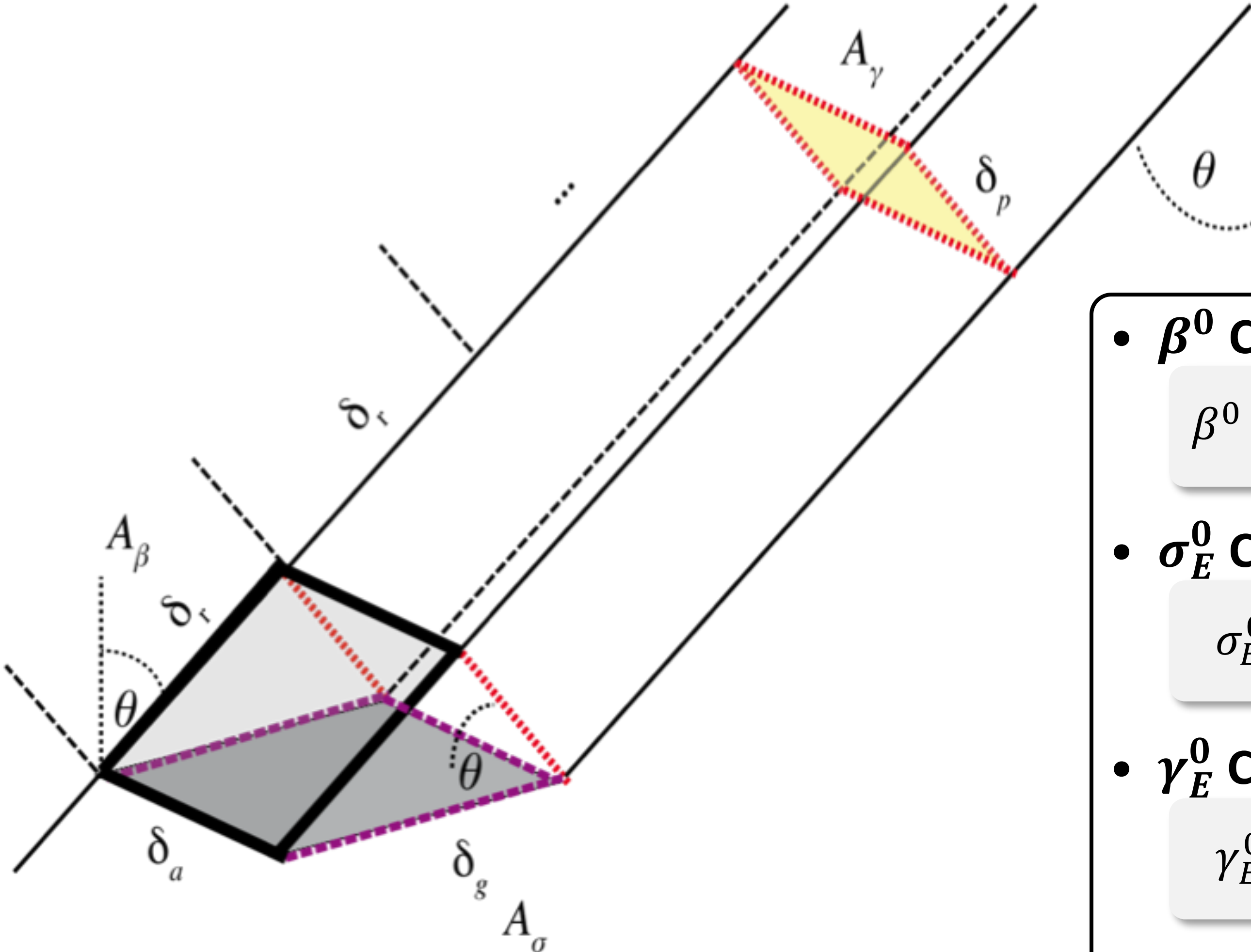
- A Geocoded and Radiometrically Terrain Corrected SAR Product Meets These Users Needs





A WORD ON THE MOST APPROPRIATE SAR BACKSCATTER NORMALIZATION

Ellipsoid-Based Backscatter Coefficient Conventions



Small (2011): Flattening Gamma, TGRS, 49(8)

- **β^0 Convention:**

$$\beta^0 = \beta / A_\beta \quad with \quad \beta = \frac{P_s}{P_i}$$

- **σ_E^0 Convention:**

$$\sigma_E^0 = \beta^0 \cdot \frac{A_\beta}{\underline{A}_\sigma} = \beta^0 \cdot sin\theta_E$$

- **γ_E^0 Convention:**

$$\gamma_E^0 = \beta^0 \cdot \frac{A_\beta}{\underline{A}_\gamma} = \beta^0 \cdot tan\theta_E$$

Lower bar for $\underline{A}_\gamma$ and $\underline{A}_\sigma$ indicates that flat-earth assumption is applied

DTM-Based Backscatter Coefficient Conventions

- **Traditional Local Incidence Angle-Based Terrain Normalization:**

$$\sigma_T^0 = \beta^0 \cdot \frac{A_\beta}{A_\sigma} = \sigma_E^0 \cdot \frac{sin\theta_{LIM}}{sin\theta_E}$$

  - Several limitations leading to limited terrain flattening performance:
    - Terrain within one resolution cell is assumed smooth → bias in A_σ
    - Non-homomorphic nature of the slant-range to map-geometry projection is ignored
    - The estimate of local area is not projected into the plane perpendicular to slant range (gamma naught standard).

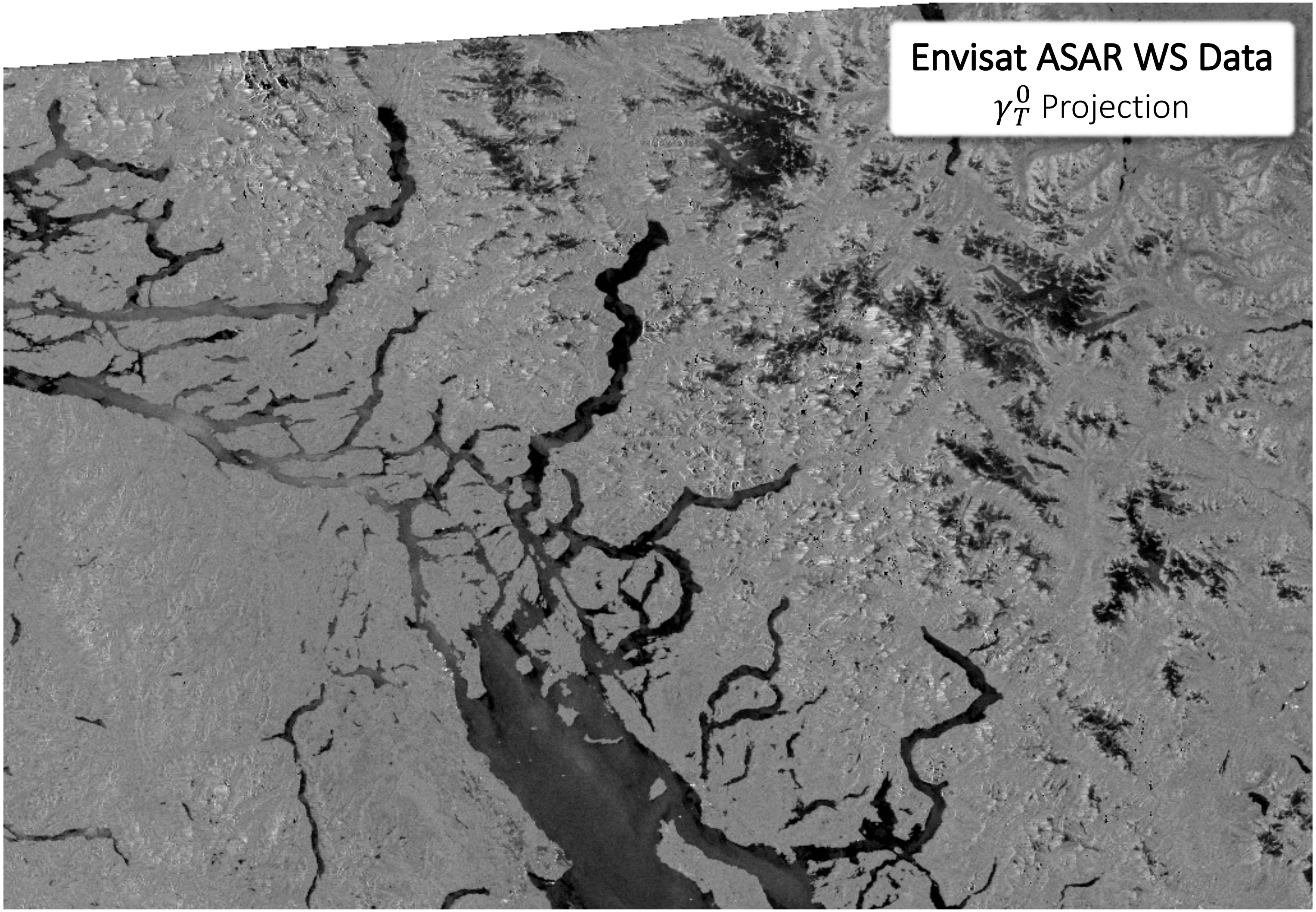
- **Terrain-Corrected Gamma Naught (Small, 2011):**

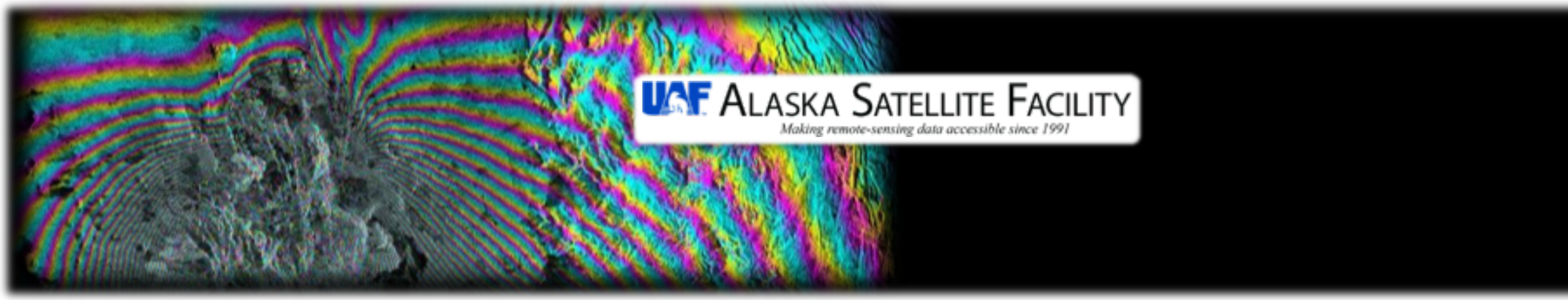
$$\gamma_T^0 = \beta^0 \cdot \frac{A_\beta}{\int_{DTM} A_\gamma}$$

  - Calculates area covered by a resolution cell by integrating over DTM facets in 3D space

Comparisons of σ_T^0 and γ_T^0 have shown superior performance of the γ_T^0 convention

Example of σ_T^0 vs γ_T^0 Performance

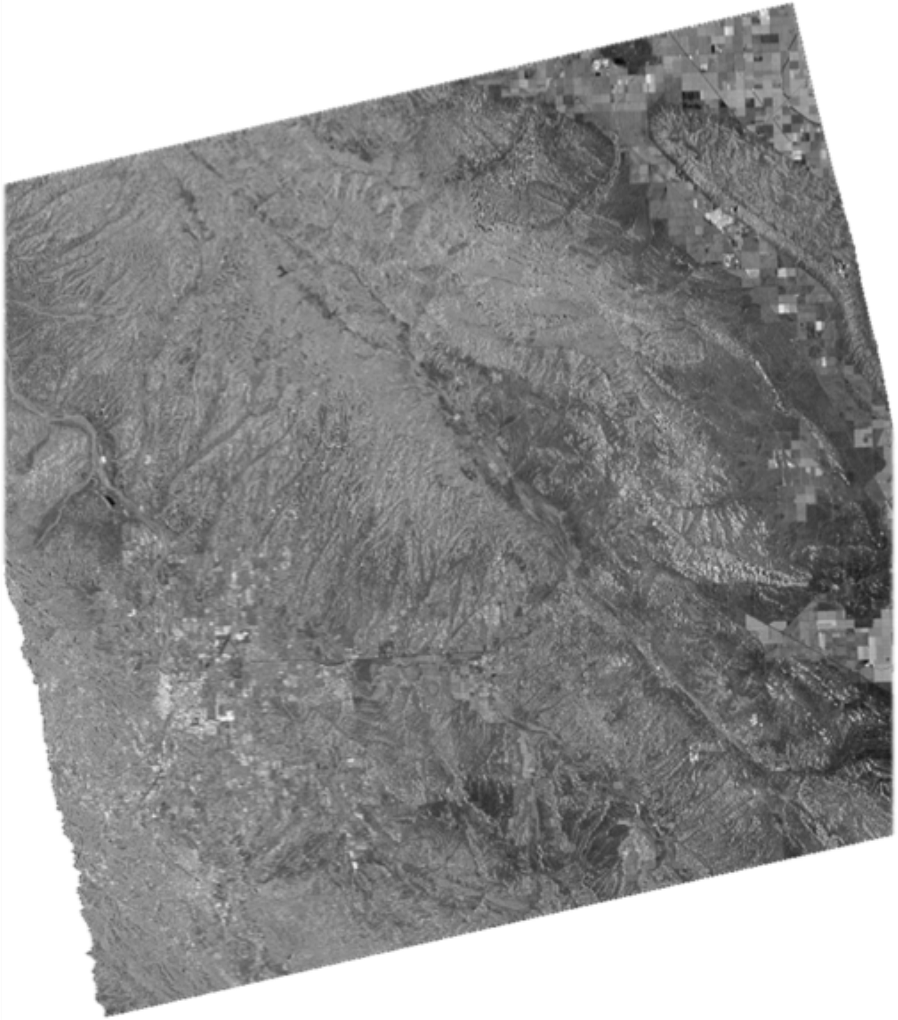




IMPLEMENTING AND TESTING PROTOTYPE γ_T^0 WORKFLOWS FOR S-1

RTC Processing Flows for SNAP and GAMMA

SNAP RTC Production

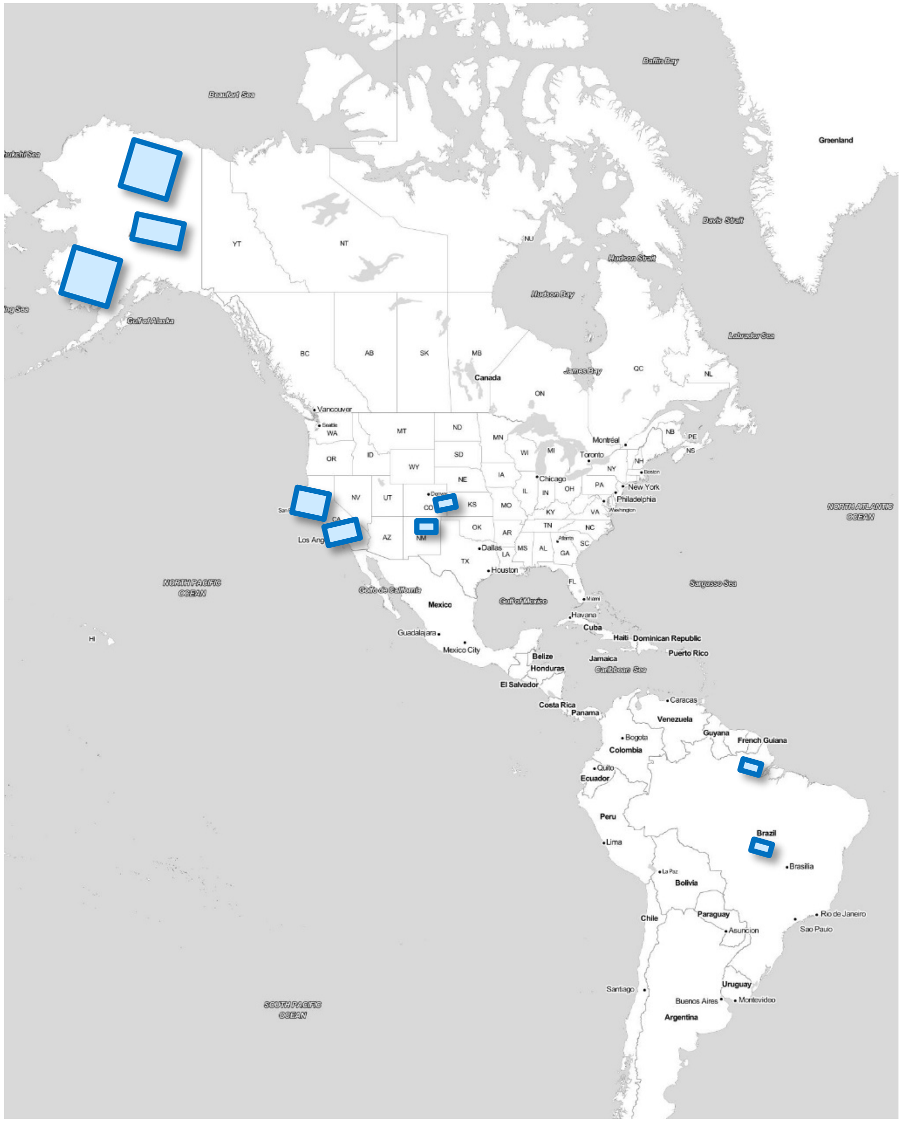


GAMMA RTC Workflow (ATBD)

Comparing RTC Performance

- **Nine Sites across the Americas**
  - (1) Amazon hills; (2) Mato Grosso Brazil; (3) Delta Junction, Alaska; (4) Fairbanks, Alaska; (5) Yukon-Kuskokwim river delta; (6&7) two locations in California; (8) Kansas; and (9) New Mexico
  - Variety of terrain and surface types

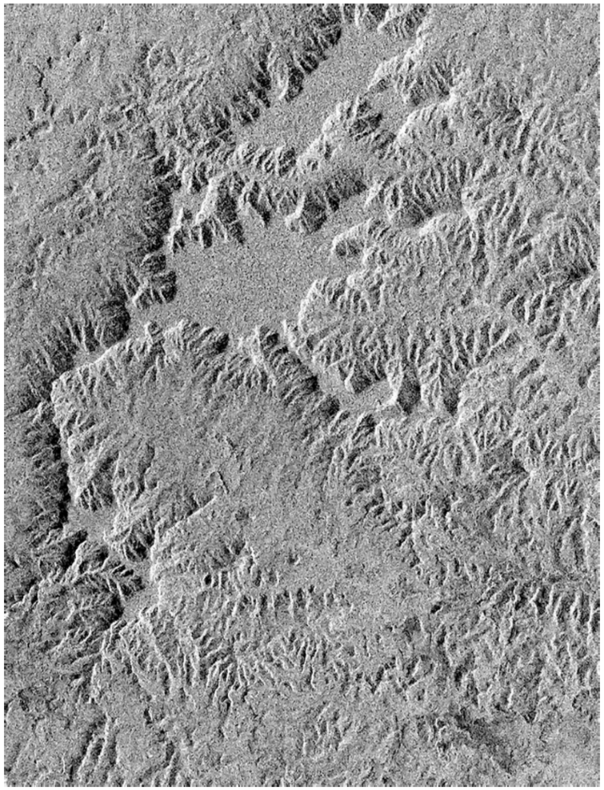
- A total of 42 scenes were processed using both the GAMMA and SNAP workflows
- Both radiometric & geometric accuracy was analyzed against data with known quality:
  - Relative to each other
  - GAMMA-produced ALOS RTC products
  - Relative to other geocoded imagery



Selected Results

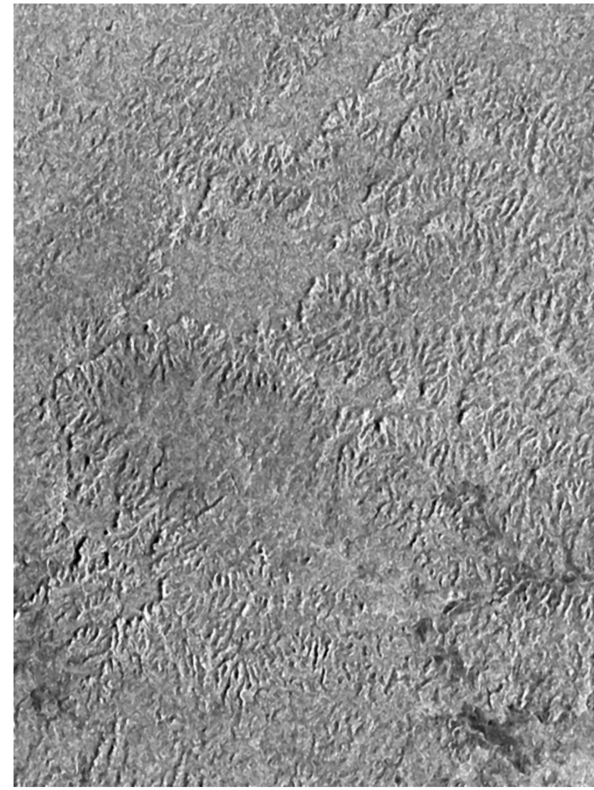
Visual Comparison Test Site: Amazon Hills

GTC IMAGE (γ_E^0)



GAMMA RTC ($\gamma_{T;GAMMA}^0$)

SNAP RTC ($\gamma_{T;SNAP}^0$)



Visual Comparison:

- GAMMA RTC provides better terrain flattening
- GAMMA RTC shows better geolocation quality than SNAP RTC

Selected Results

Visual Comparison Test Site: Fairbanks Alaska

GTC Image (γ_E^0)

GAMMA RTC ($\gamma^0_{T;GAMMA}$)

SNAP RTC ($\gamma^0_{T;SNAP}$)

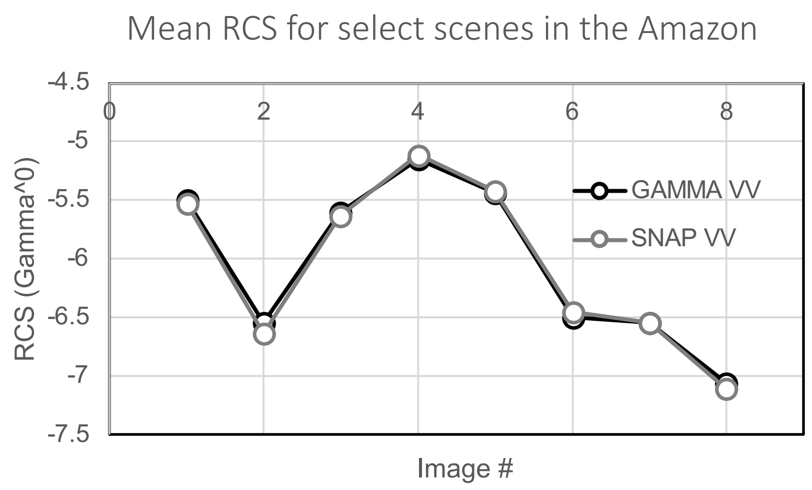
Visual Comparison:

- GAMMA RTC provides better terrain flattening
- GAMMA RTC shows better geolocation quality than SNAP RTC
- Lower DEM resolution & Quality → reduced RTC performance

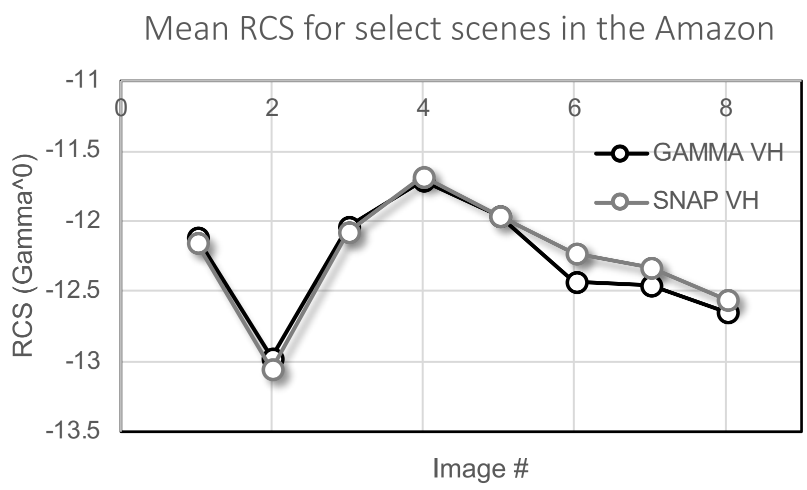
Selected Results

Comparison of Radiometric Calibration

- To evaluate radiometric calibration, average $\gamma^0_{T;GAMMA}$ and $\gamma^0_{T;SNAP}$ values were calculated over CEOS Amazon calibration sites
- **Findings**:
  - No appreciable difference in radiometric calibration between $\gamma^0_{T;GAMMA}$ and $\gamma^0_{T;SNAP}$
  - Interesting seasonal dependence of RCS in C-band



AVERAGE RCS - VV



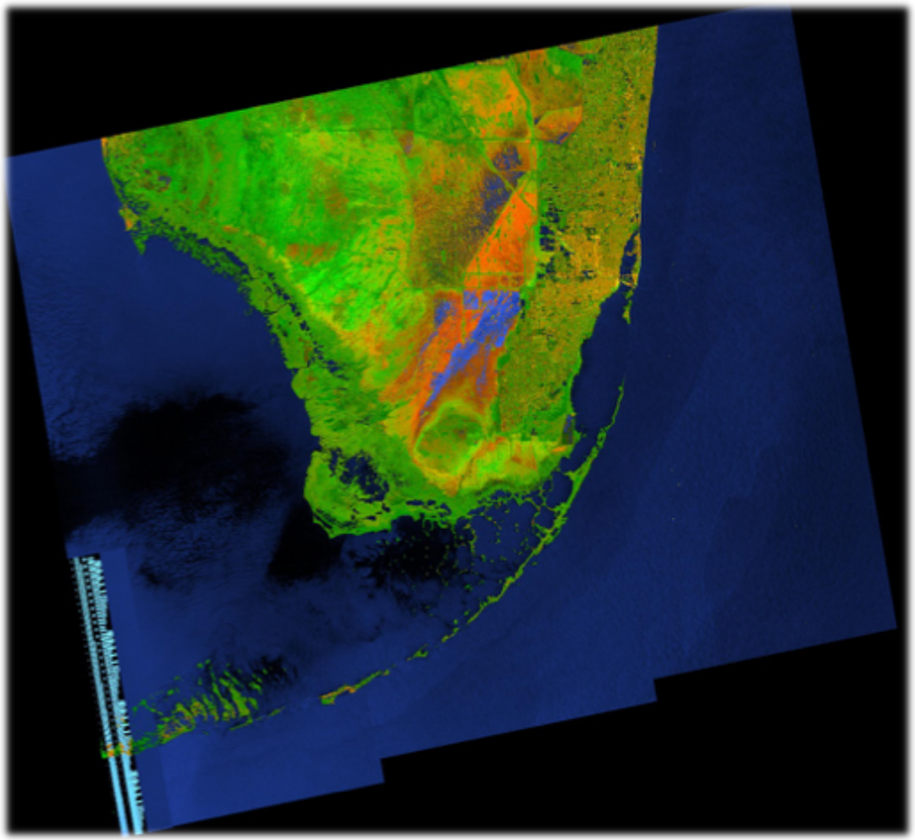
AVERAGE RCS - VH

Selected Results

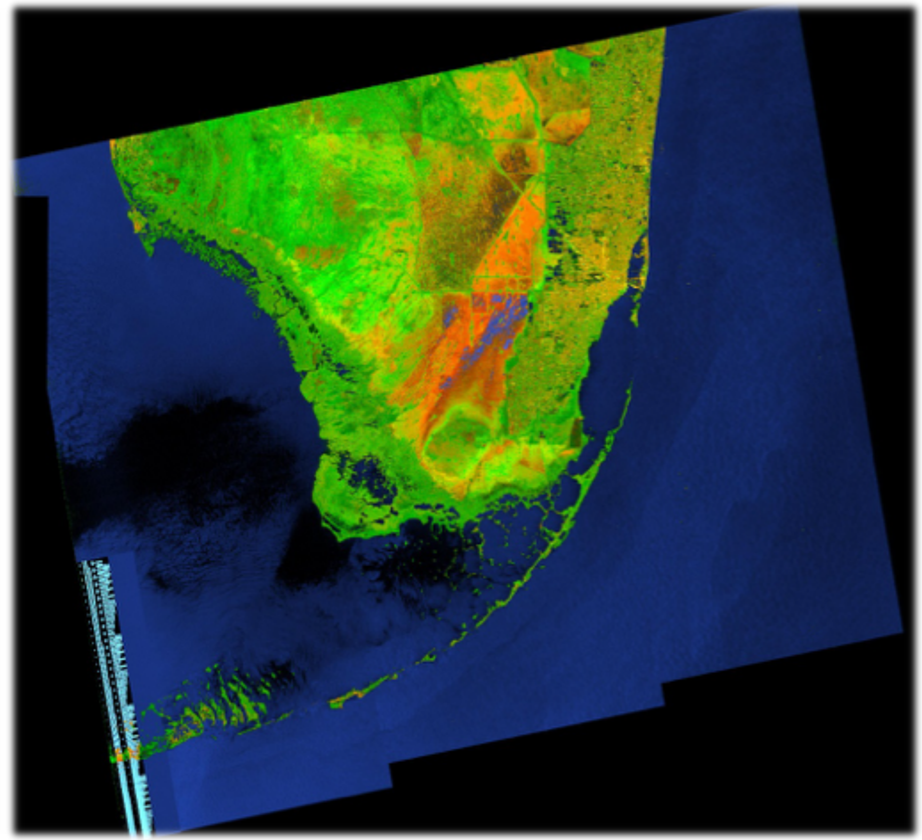
Comparison of Resolution / Equivalent Number of Looks

- Traditional methods for NoL calculation in geocoded data not useful → Calibration patterns added to test images before RTC production and geocoding

GAMMA RTC ($\gamma^0_{T;GAMMA}$)



SNAP RTC ($\gamma^0_{T;SNAP}$)



Selected Results

Comparison of Resolution / Equivalent Number of Looks

- **Results**:

	pixel size (m)	**resolution (m)** [measured from artificial targets]	**# Looks** [estimated from artificial targets]	**# Looks** [measured from artificial noise patterns]
Simulated	10.0	21.0	5.0	4.8
Florida	10.0	21.0	5.0	5.3
Fused	10.0	21.0	5.0	5.5
GAMMA	30.0	30-40	10.2	15.6
SNAP	30.0	30-40	10.2	6.7
SNAP Speckle filtered	30.0	30-40	10.2	57.0

- **Interpretation**:
  - For heterogeneous regions, the resolution of GAMMA and SNAP products are comparable
  - The physical resolution of GAMMA RTC products is more spatially consistent with # looks estimated from heterogeneous regions and homogenous regions being similar
  - SNAP RTC products without additional Speckle filtering appear noisy
  - After Speckle filtering, the physical resolution of SNAP processed data varies widely depending on target type, suggesting that an adaptive filter was used

Selected Results

Other Factors: Geolocation Accuracy & Processing Time

- **Geolocation Accuracy**:
  - Geographic location assessment was done by comparing GAMMA and SNAP RTC data to ortho imagery source data
  - **GAMMA**: No measurable offsets (relative to the quality of the reference data)
  - **SNAP**: No measurable azimuth offsets; 10 – 40m range offsets

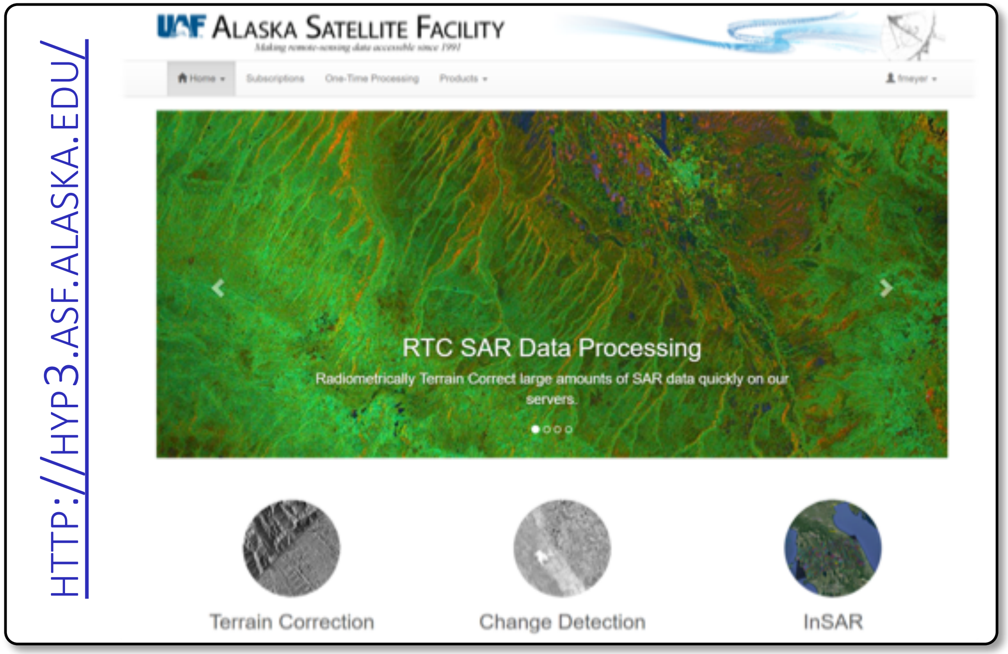
- **Throughput & Other Factors**:

Category	GAMMA RTC	SNAP RTC
IW Run Time (30 m)	18 minutes	30 minutes
IW Product Size (30m)	190 MB	280 MB
IW Product Size (10m)	1.72 GB	2.6 GB

  - GAMMA RTC flow showed shorter processing times
  - GAMMA provides detailed log files for each processing steps → valuable in QA/QC

Conclusion and Next Steps

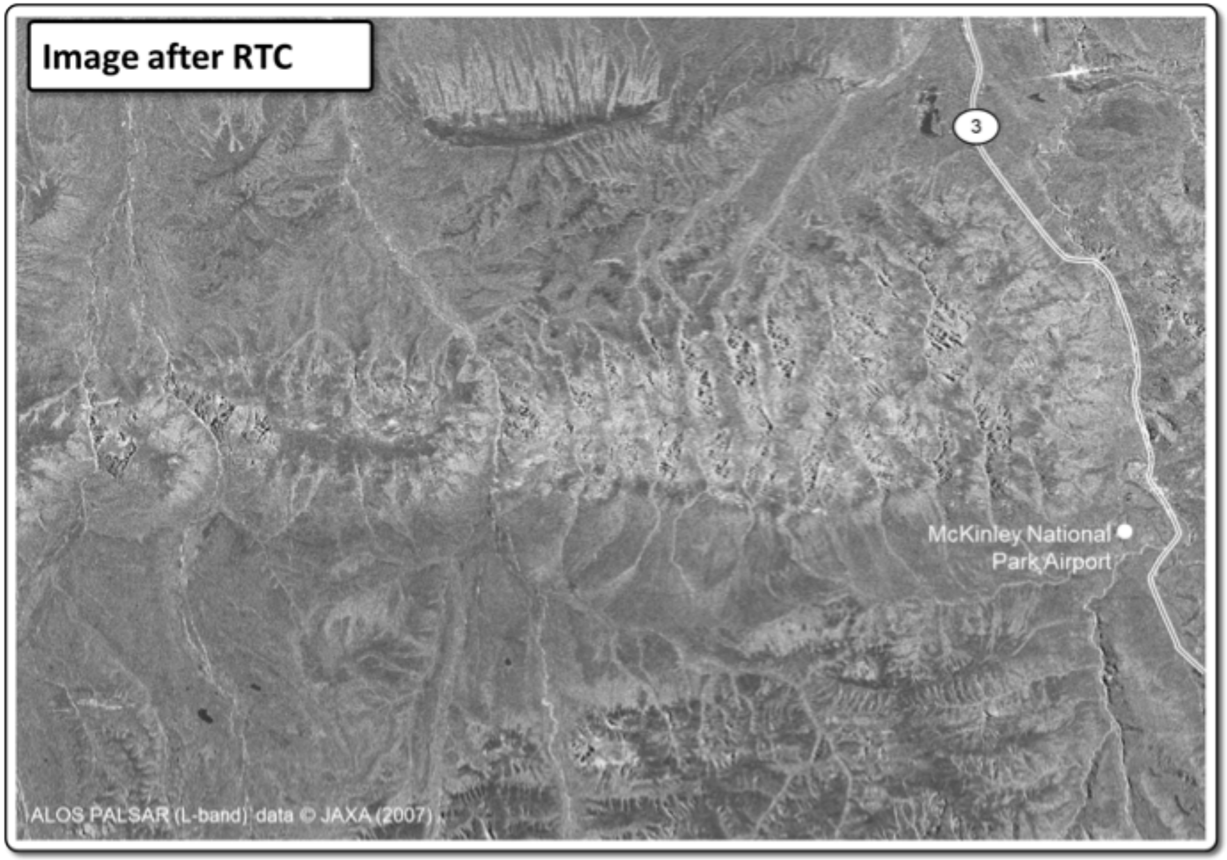
- **RTC Workflows implemented for testing operational RTC production from Sentinel-1 SAR data**
- **Relative Performance Evaluation of GAMMA- and SNAP-based RTC Products:**
  - Both GAMMA and SNAP RTC processors provide decent terrain flattening
  - However, GAMMA RTC processor shows higher and more consistent product quality (RTC performance; resolution; geolocation)
  - GAMMA processor indicated higher throughput performance
- **Next Steps**:
  - Test products were handed over to SAR community for external evaluation
  - Both SNAP and GAMMA RTC production available through HyP3 for beta-testing



Sign up at http://hyp3.asf.alaska.edu/ and help us beta-test our products

(automatic production of RTC, d-InSAR, Change Detection Maps; RGB Composites)

Final note …



ASF is also Providing Free-And-Open GIS Ready RTC Data for the Entire ALOS PALSAR Archive @ https://vertex.daac.asf.alaska.edu/