NEW DIRECTIONS AND STUDIES FOR A US SPACEBORNE SAR MISSION

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The DESDynI Saga

"Get creative …"

- In June 2011, NASA directed JPL to study Synthetic Aperture Radar mission options that fit within available funding, under several funding scenarios for the Earth Science Division
- Launch dates and mission duration were to be considered flexible, with additional funds available in later years

"… but focus on affordability"

- The team was directed to explore affordable options, including international collaboration, and associated risks
- Science should be influenced, but not constrained, by the Decadal Survey
- Saving cost may come at expense of payload or mission capability

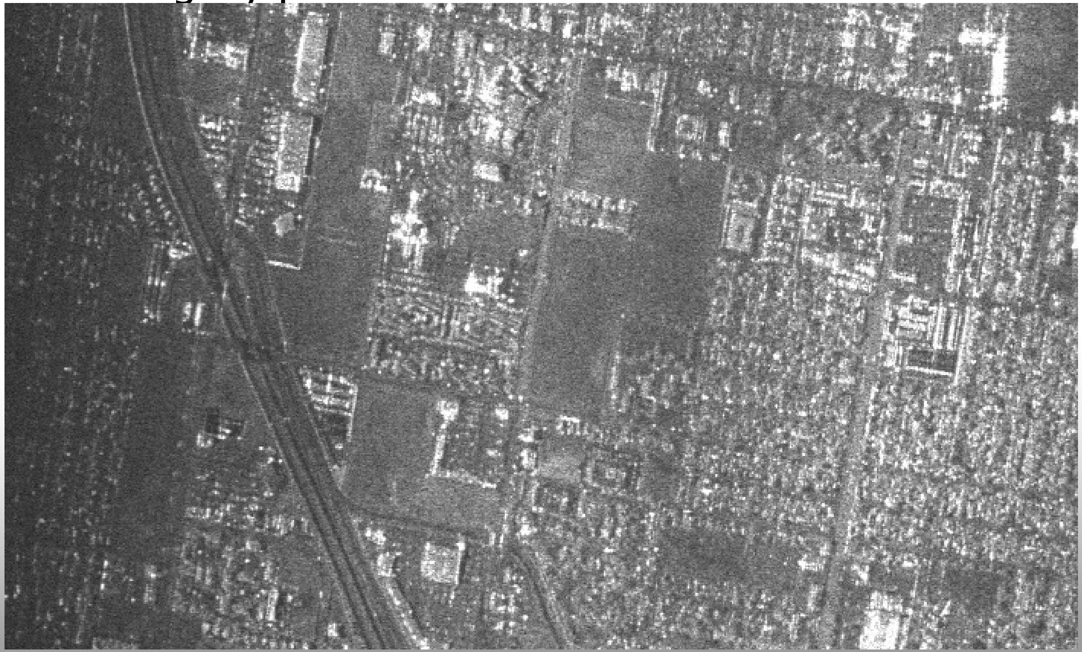
- Studies were conducted with input and feedback from DESDynI Science Study Group

Concepts studied

- Five general concepts were explored, with variants on each
  1. US-only scaled back radar capability to single-pol, half-swath
  2. <u>US-only scaled back to fit in smaller launch vehicle</u>
  3. International partner co-develops Tandem L-band radar spacecraft
  4. International partner provides spacecraft; multi-frequency mission
  5. <u>International partner provides spacecraft, and launch vehicle; multi-frequency mission</u>
- For all concepts, the fundamental reflector-based SweepSAR architecture was preserved
  - Previous studies suggested significant cost penalties for planar arrays of this size class
  - Strong investment in current instrument risk reduction activities (see next slide)
- Remainder of this talk will focus on concepts 2 & 5 above

SweepSAR Airborne Demo Data Processing

- Invested in demonstration of SweepSAR in an airborne environment using Ka-band multi-channel prototype system
- Hardware and processing demonstrate efficacy of SweepSAR in configurations that are not ambiguity limited
- Future tests will explore transmit blanking gaps and ambiguity performance.



DBF Image from Flight Line 3

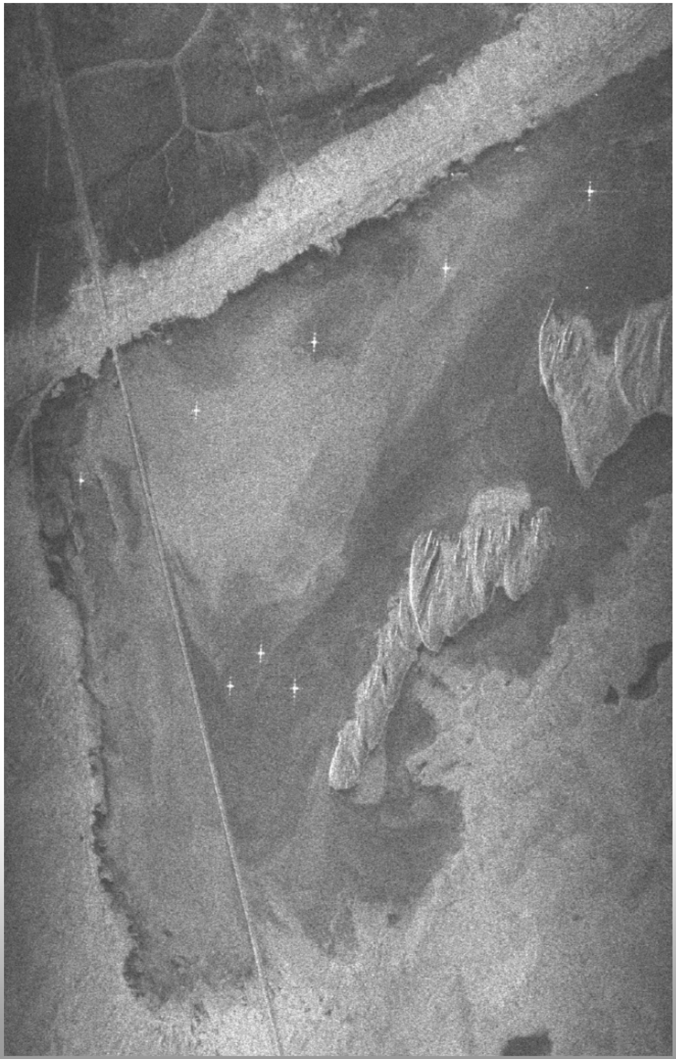


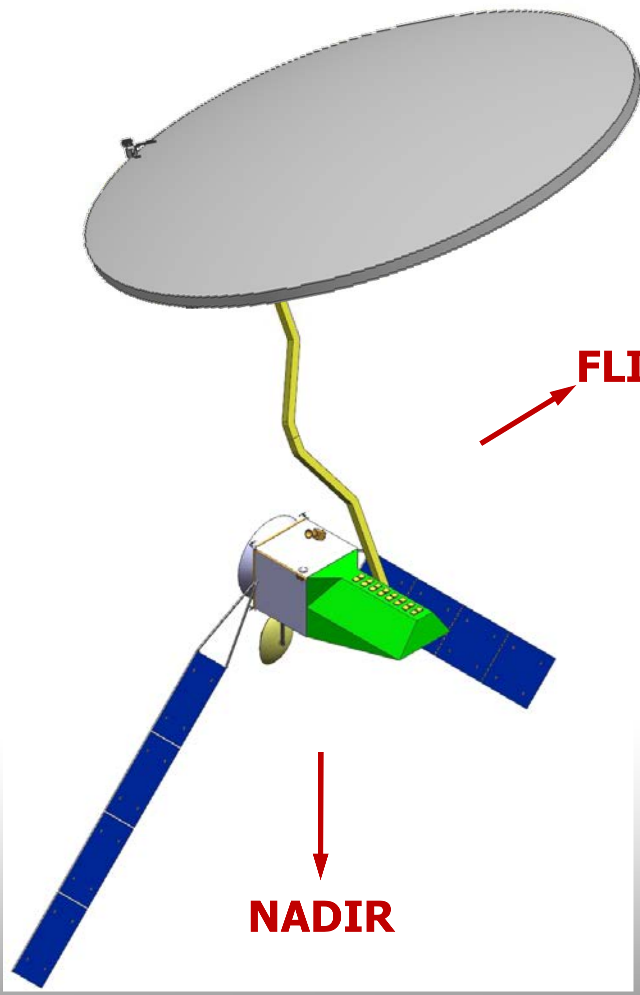
Image from Flight Line 7

Case Study for Scaled-down Flight System

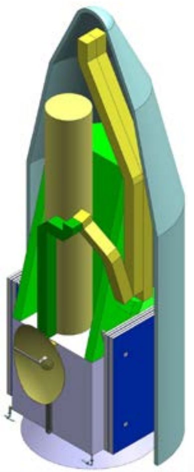
- Mission Concept Summary – fast-repeat focus
  - Allow reduced coverage and science, including polar coverage
  - Require 2-day repeat
  - Allow narrow-swath observations over select areas (e.g. Los Angeles) for response.
  - Preserve SweepSAR with reflector (9-m reflector; 8 element feed)
  - Preserve quad-pol or dual-pol
  - Consider L-band or S-band

- Science
  - Not a global science mission; targeted science for fast-evolving areas, and response

Scaled-down Flight System Configuration



9m-Diameter Reflector



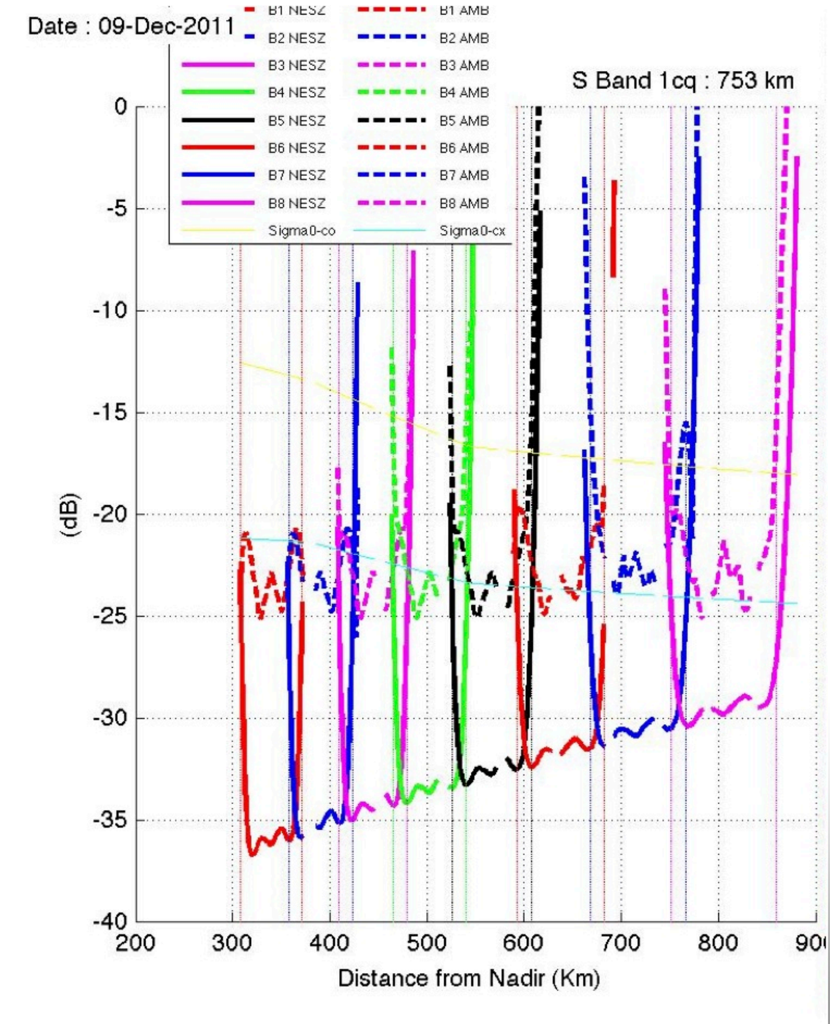
Minotaur IV class fairing

Previous designs required 12-15 m reflectors, double-length feed, and considerably larger launch vehicles

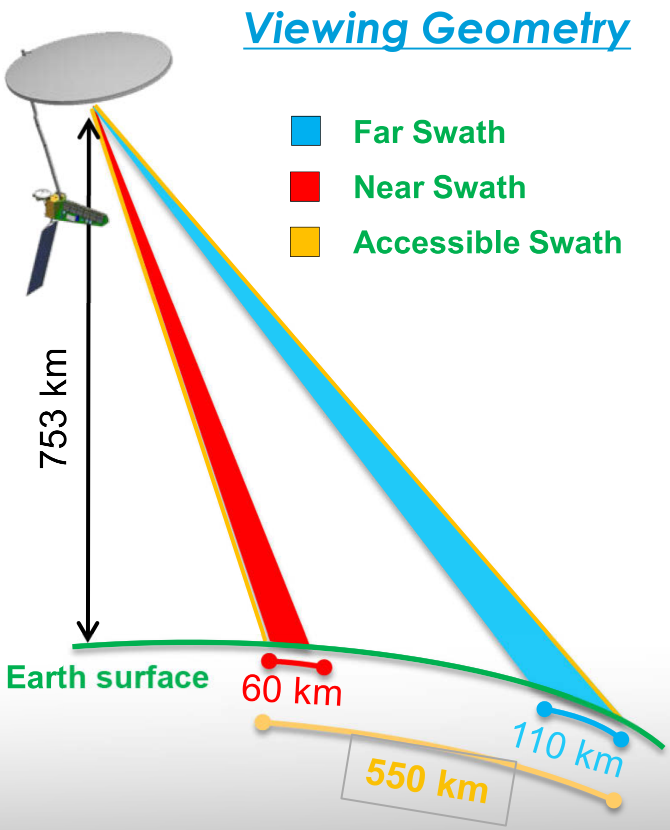
Radar Quad-Pol Performance, Case 2

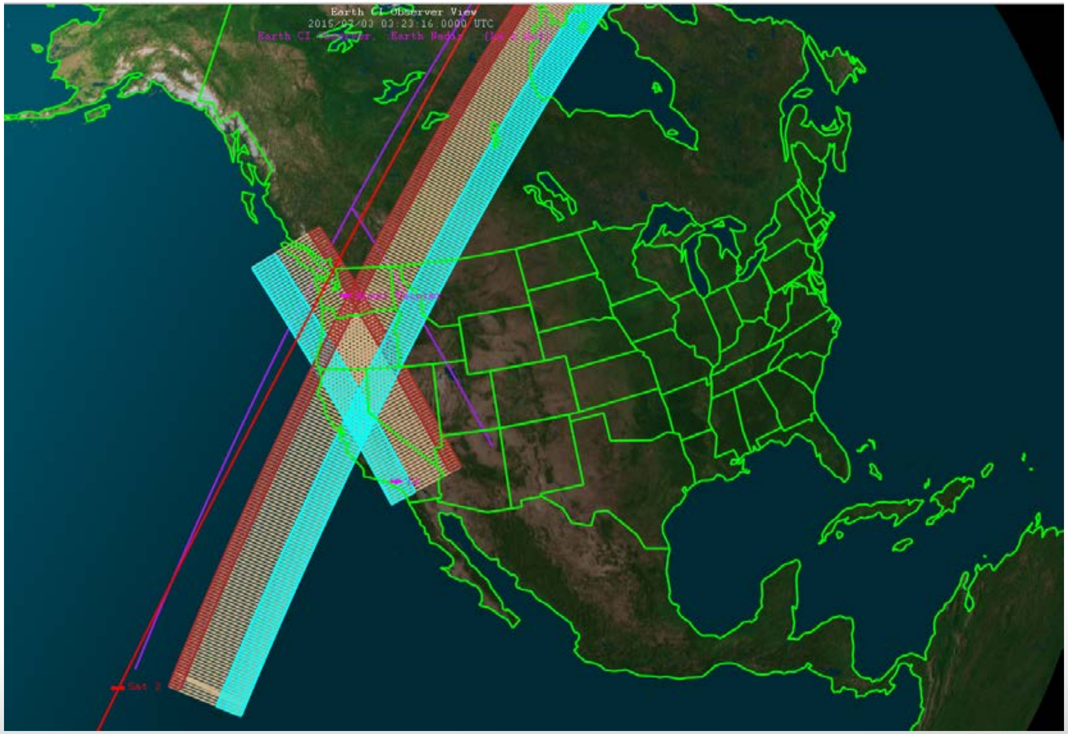
- S-Band
- 8-Beam, 3-taps
- 40 MHz BW
- 550 km accessible swath
  - 24-54º incidence angle range
  - < -25dB NEσ_0
  - < -20dB Ambiguity
- 8 Boresight Roll Angles for full coverage

- Key Parameters:
  - PRF: 3000-3800 Hz
  - Processing BW: 1100 Hz
  - Pulse width: 40 μsec



Two-day repeat orbit regional access

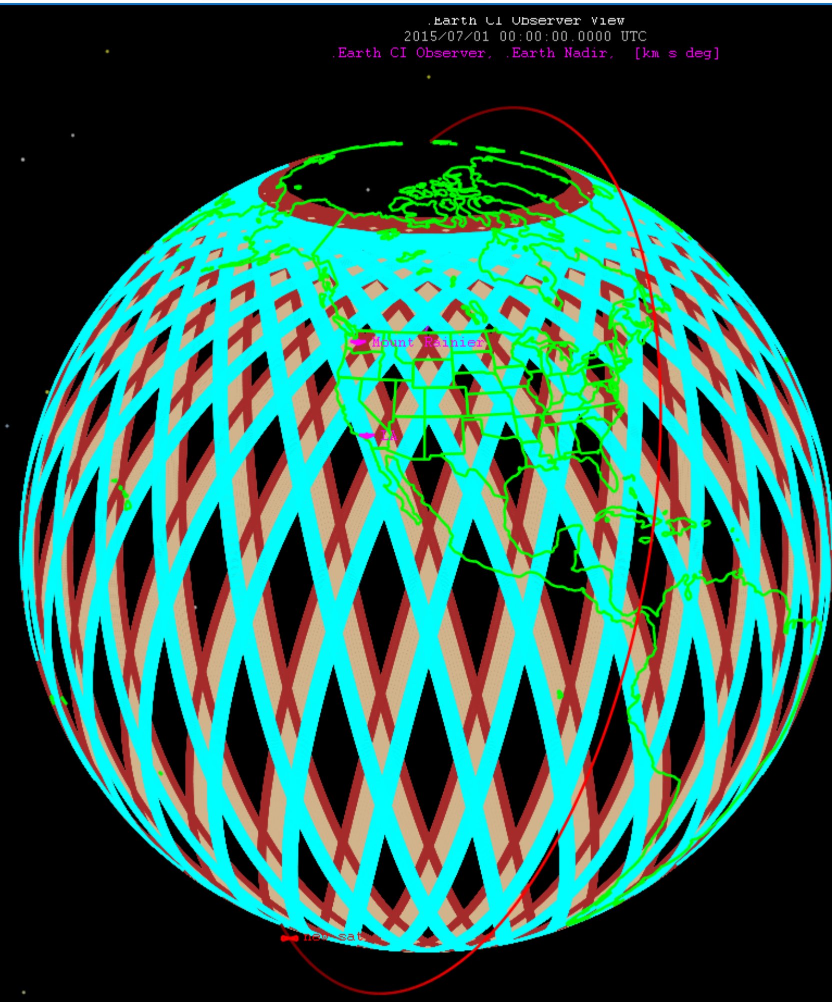




8 Boresight Roll Angles for full coverage of access area

Two-day repeat orbit global access

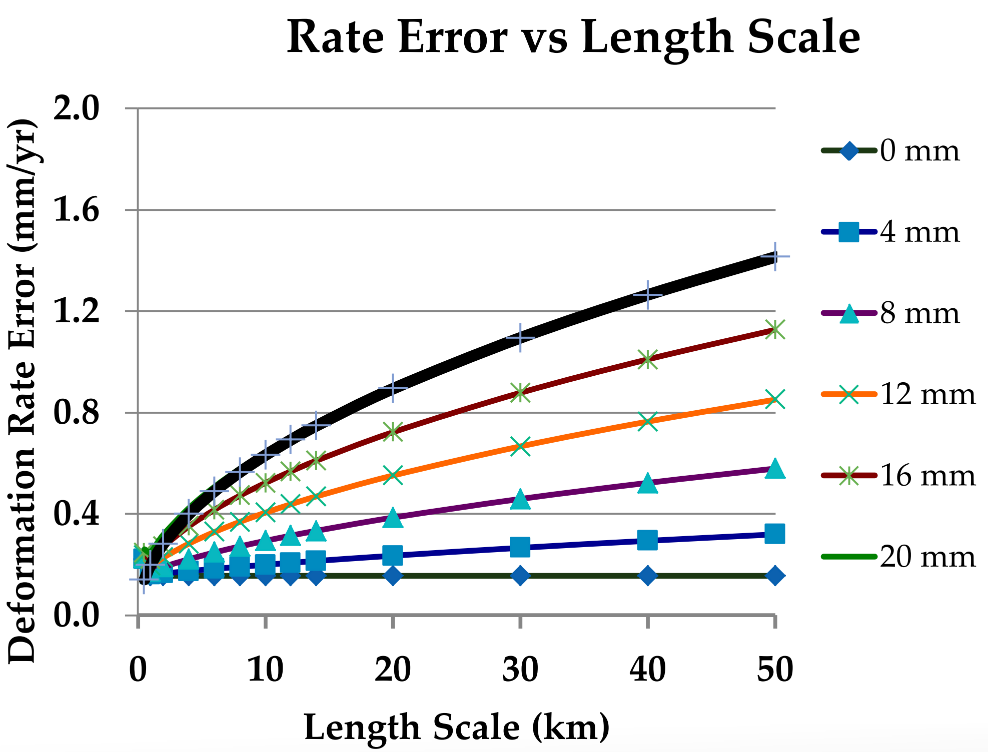
- Swaths are defined according to spacecraft roll position
- Access extent limited by performance thresholds, not roll limitations
- Additional swath is available at lower performance
- Yaw flip would allow additional access regions
- Due to roll-rate limitations, beam steering is not agile
    - Systematic regional acquisition plan



Interseismic Requirements over Scale
L-band Performance

Assumptions	
Radar Mode	Single-Pol 20+5MHz
Repeat Interval Interferogram	13 days 600 days
Observations	Asc & Des
Wavelength	24 cm
Correlation+	$\gamma_0 e^{-t/T}$, T = 200 days (γ < 0.1 per interferogram)
Atmosphere	20 mm
Product Resolution	1000 m x 1000 m
Pointing	Left or Right
Stacking Period	3 years

+ γ_0 includes SNR, Geom, Vol Correlations

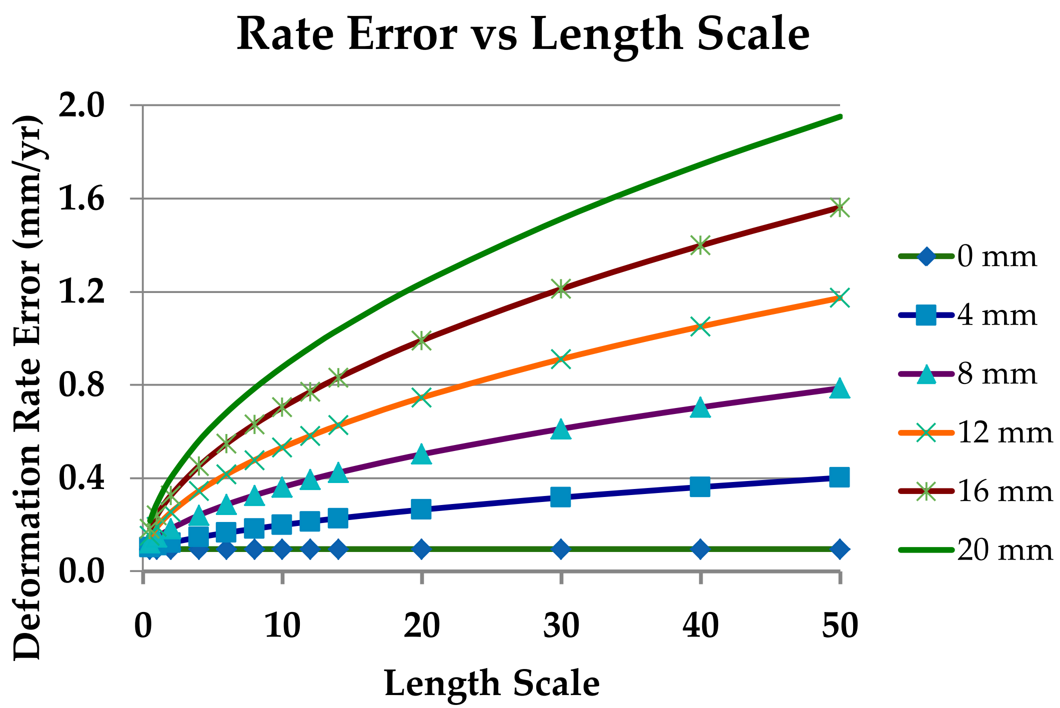


- ✓ 2-D vector measurements through ascending/descending, right or left
- Margin introduced through additional data not considered
  - Polarimetric data
  - Overlap due to orbit convergence

Interseismic Requirements over Scale
S-band Performance

Assumptions	
Radar Mode	Single-Pol 20MHz
Repeat Interval Interferogram	2 days 120 days
Observations	Asc & Des
Wavelength	13 cm
Correlation+	$\gamma_0 e^{-t/T}$, T = 60 days (γ < 0.1 per interferogram)
Atmosphere	20 mm
Product Resolution	1000 m x 1000 m
Pointing	Left or Right
Stacking Period	3 years

+ γ_0 includes SNR, Geom, Vol Correlations

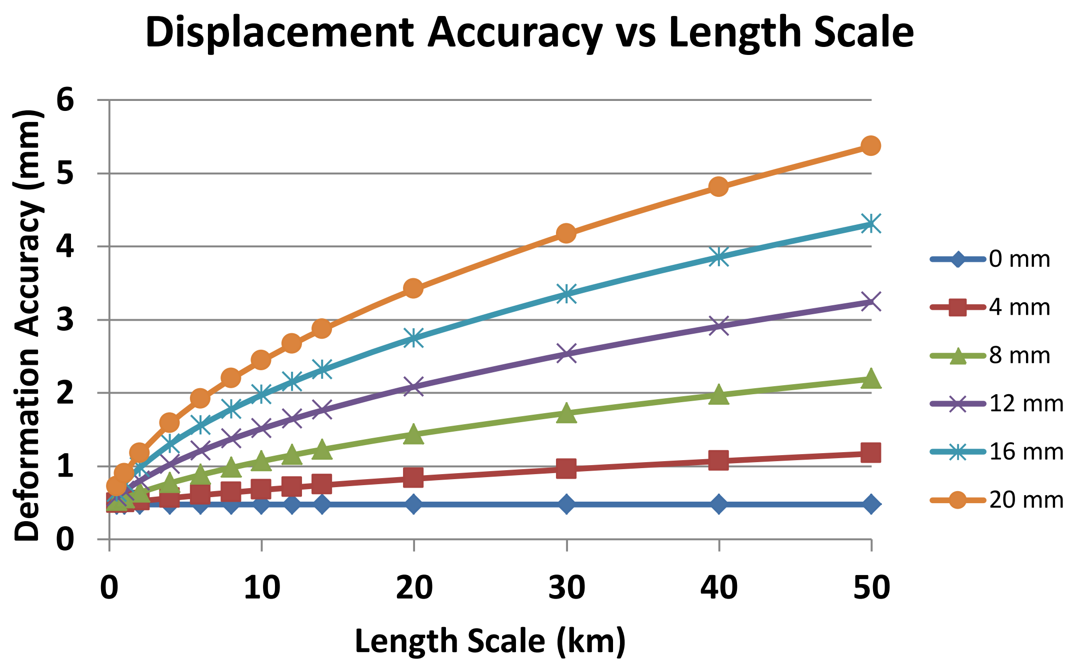


- S-band performance reasonably well due to large number of interferograms to reduce noise
- For interseismic applications, atmosphere dominates, so long interferograms are preferable, favoring longer wavelength systems

Targeted Deformation Performance at S-band

Assumptions	
Radar Mode	Single-Pol 20MHz
Repeat Interval Interferogram	2 days 14 days
Observations	Asc & Des
Wavelength	13 cm
Correlation+	$\gamma_0 e^{-t/T}$, T = 60 days
Atmosphere	20 mm
Product Resolution	20 m x 20 m
Pointing	Left or Right
Stacking Period	1 month

+ γ_0 includes SNR, Geom, Vol Correlations



- For targeted phenomena, one can use short period interferograms in short stacks to beat down atmosphere noise
- At S-band additional bandwidth is available for finer resolution imaging for response applications
- L-band & S-band performance are similar

Case Study for Partnered Science

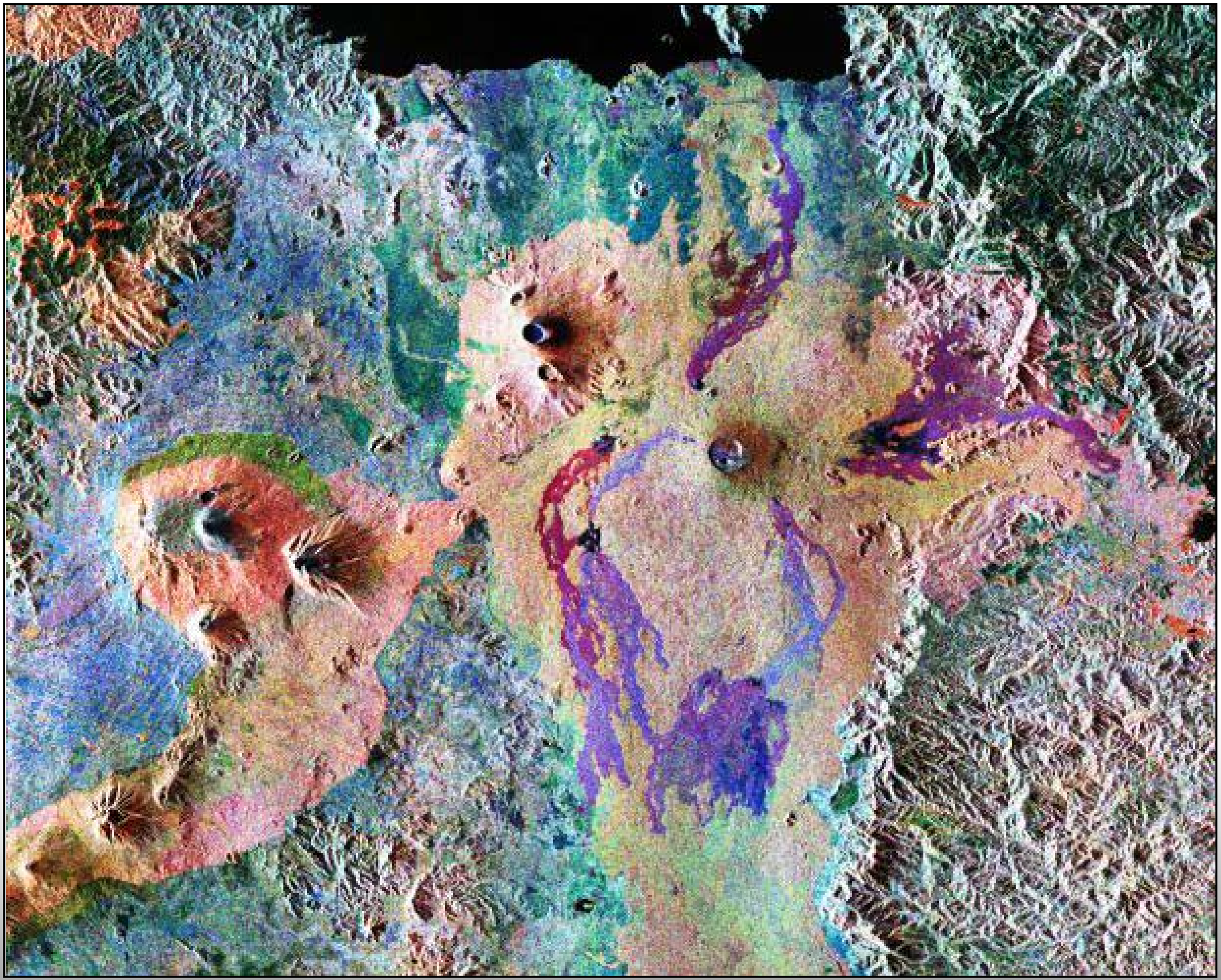
- All international partnerships recognized the benefits of frequency and/or baseline diversity
- For this presentation, we consider dual-band, shared-reflector case
  - Preserve SweepSAR with reflector (12-m reflector; multi-element feed)
  - Preserve quad-pol or dual-pol
  - Consider L-band and S-band dual-band capability
  - Attempt to design for good performance during simultaneous operation
  - Consider 12-day repeat

- Science
  - Global science mission preserving original L-band radar objectives
  - Targeted science studies where S-band or dual-band is most suitable

Benefits of both S-band and L-band

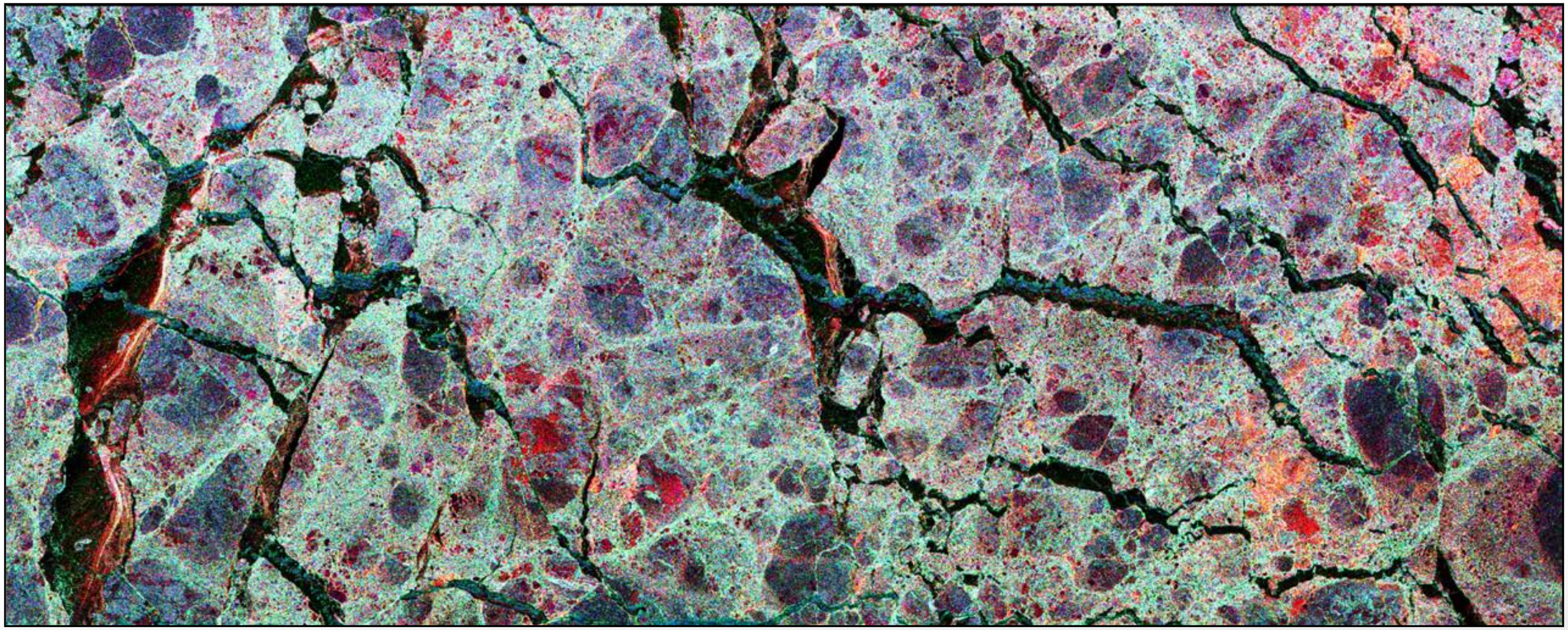
- Globally distributed measurements at S-band for science applications would be an interesting new data set
- Combination of simultaneous S-band and L-band data would be extremely powerful for discriminating differential scales in many disciplines
- In combination, extends the accuracy of low biomass (< 100 Mg/ha) estimates, and sensitivity to regrowth
- Interferometric Correlation at S-band intermediate between C-band and L-band
  - Improves estimate of the ionospheric path delay relative to split spectrum methods where correlation is good (i.e. in moderate to low vegetation)
  - Extends range of deformation sensitivity to lower values where correlation is good
- Greater available bandwidth at S-band than L-band could enable focus on some areas at finer resolution

SIR-C/X-SAR Dual-frequency Polarimetry



Volcanoes

SIR-C/X-SAR Dual-frequency Polarimetry



Weddell Sea, Antarctica

Red: CHH Green: LHV Blue: LHH

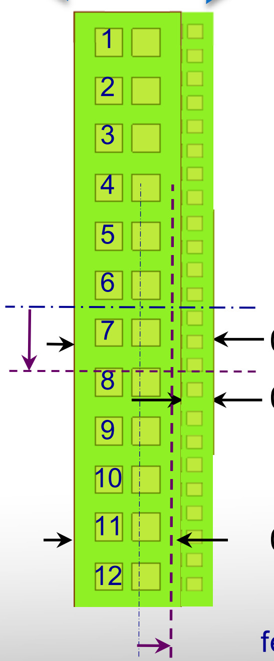
L-Band + S-Band Feed RF Aperture

12x2 L-Band Patch Array

- 18 cm el spacing
- 13 cm az spacing
- patch size: ~9 cm

24x1 S-Band Patch Array

- 8.5 cm el spacing
- patch size = λ-scaled L-Band patch size



L&S array centers aligned in elevation

Reflector Focal Point shifted off-center in elevation to improve swath

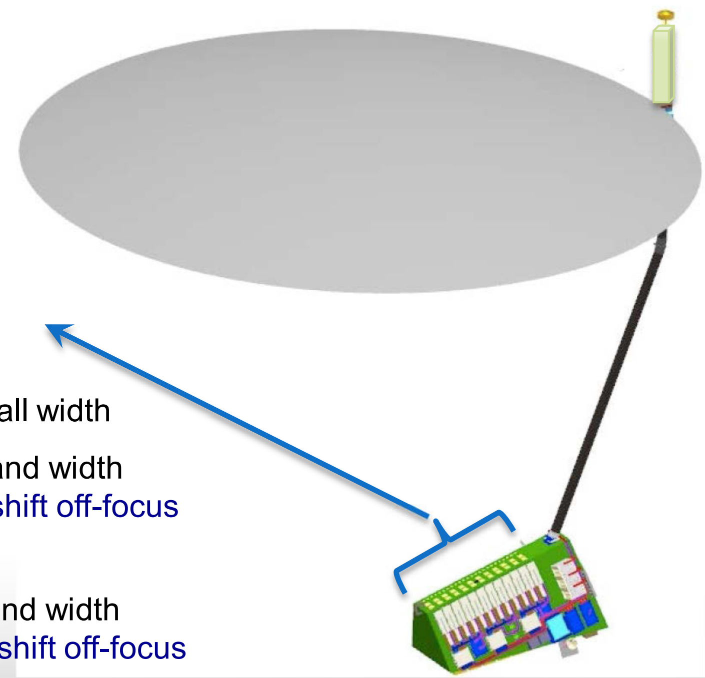
0.422m overall width

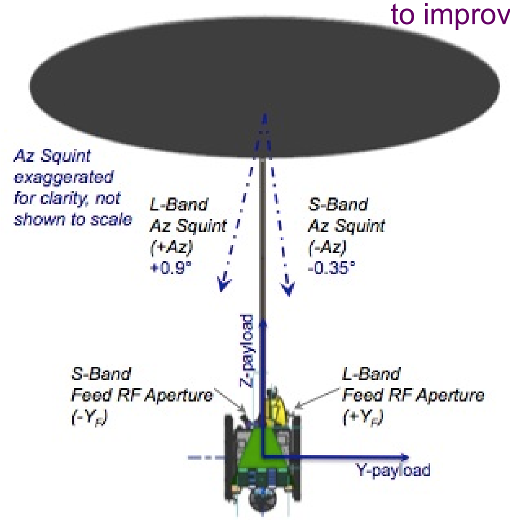
0.082m S-Band width
-0.05961m shift off-focus

0.340m L-Band width
+0.15139m shift off-focus

Reflector Focal Point shifted with respect to array centerline

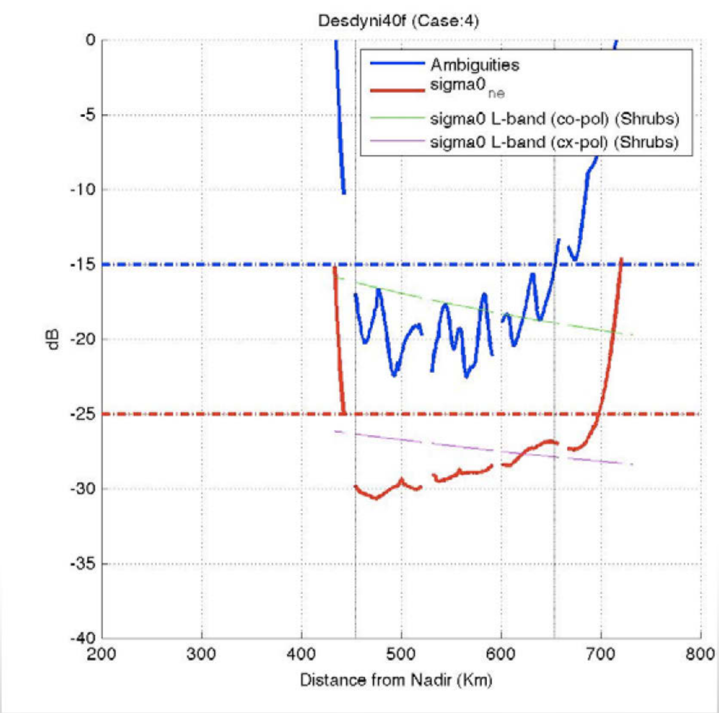
feed arrays shifted from focal point in azimuth proportional to λ to equalize squint relative to beamwidth



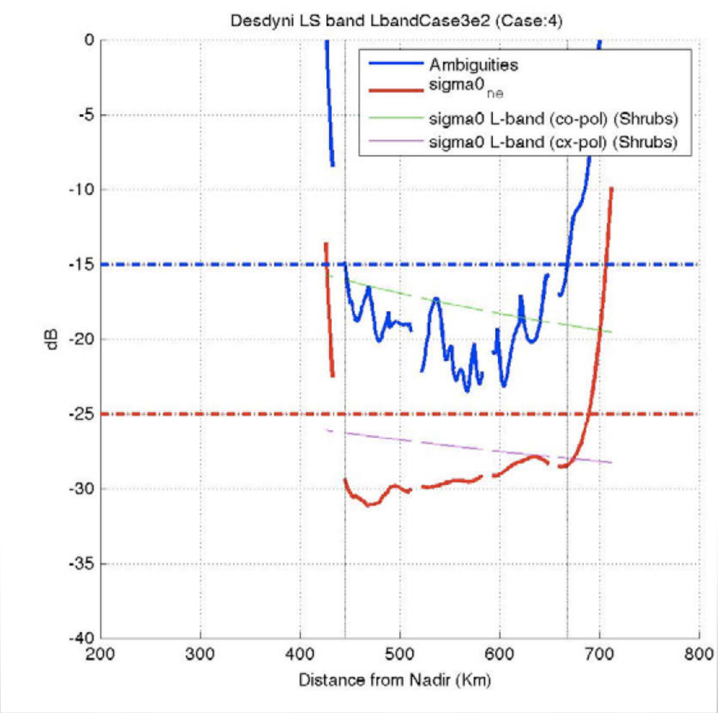


L-Band Quad-Pol Performance

Ecosystem: (true)Quad-Pol [HH, HV, VH, VV]
40 MHz Bandwidth
L-Band only, Az & El-Centered



Ecosystem: (true)Quad-Pol [HH, HV, VH, VV]
40 MHz Bandwidth
side-by-side Az & El-Shifted L-Band



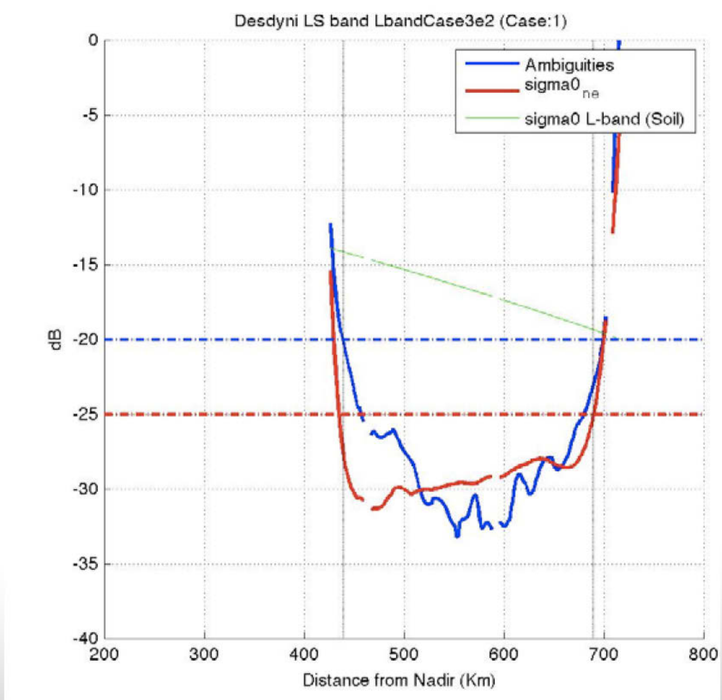
- L-Band only basis case

→

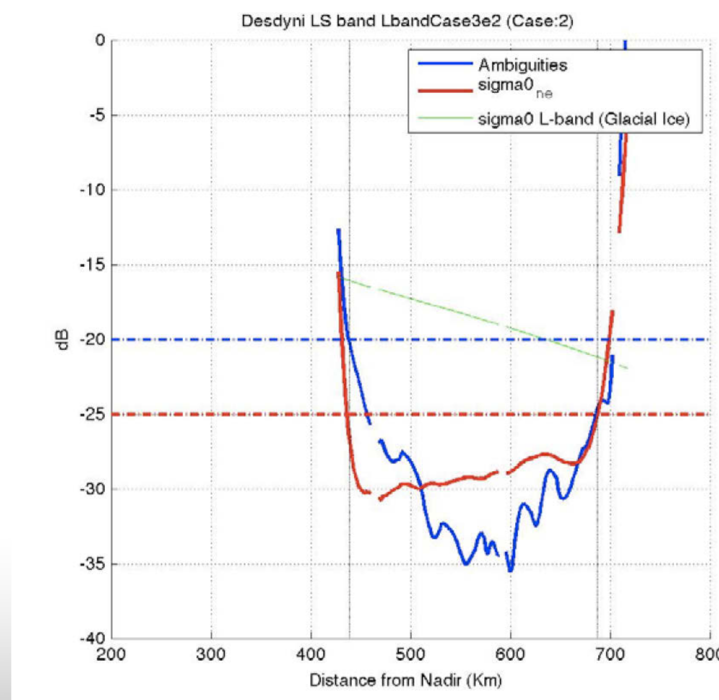
- Re-optimized to accommodate side-by-side S-Band, and to improve far-swath ambiguities

L-Band Single-Pol Performance

Deformation: Single-Pol [HH]
20+5 MHz Bandwidth
side-by-side Az & El-Shifted L-Band

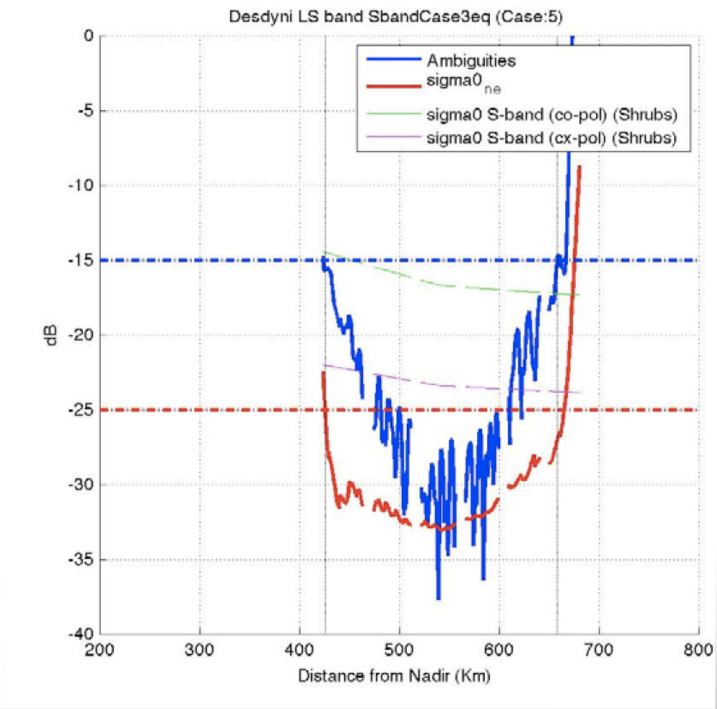


Glaciers: Single-Pol [VV]
20+5 MHz Bandwidth
side-by-side Az & El-Shifted L-Band

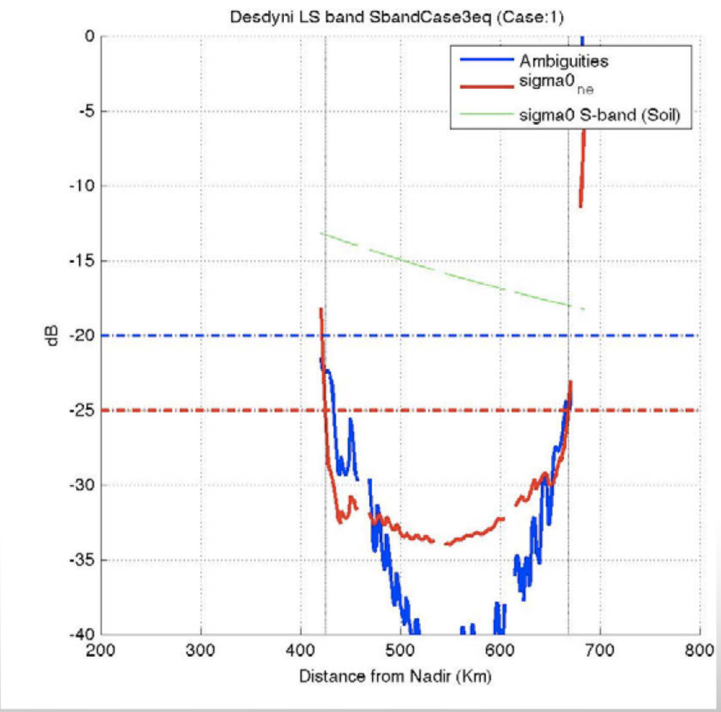


S-Band Performance

Ecosystem: (true)Quad-Pol [HH, HV, VH, VV]
25 MHz Bandwidth
side-by-side Az & El-Shifted S-Band



Deformation: Single-Pol [HH]
25 MHz Bandwidth
side-by-side Az & El-Shifted S-Band



- Continuing to optimize design and requirements to derive an implementable system within technical and programmatic guidelines

Future Plans

- NASA has directed continued studies on multiple fronts for the near term
  - Specific guidelines define the possible mission capabilities and launch dates
  - Ideas described here, among others, are being explored and appear to be within the right trade space for affordability
  - Studies consider missions with launch dates in the 2019-2021 time frames

- A science definition team has been formed to guide the science priorities of the mission, taking into account upcoming international capabilities

- Partnerships continue to be the most likely means of developing a mission NASA considers affordable
  - Partnership discussions continue at the technical and programmatic levels at NASA