Australia's National Science Agency

Recent Spaceborne SAR Developments and Opportunities

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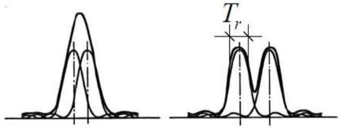
Spaceborne SAR Systems and Applications

SAR Imaging Geometry and Range & Azimuth Resolution of a SAR System

- *Range Resolution* depends on the bandwidth or pulse duration of transmitted signal

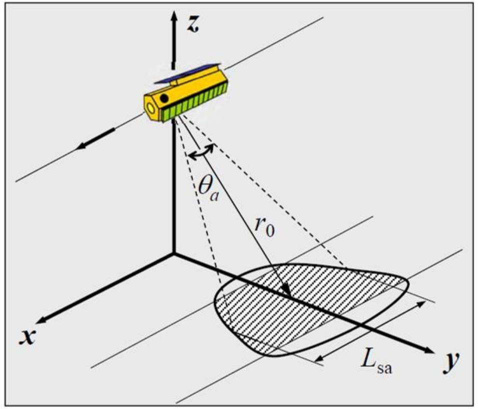
$$\delta_r = \frac{c_o}{2.B_r}$$



$$T_r = \frac{1}{B_r}$$

- Length of the synthetic aperture: L_{sa}

$$L_{sa} = \theta_a . r_o = \frac{\lambda}{d_a} . r_o$$



- Beamwidth of the synthetic antenna: θ_{sa}

$$\theta_{sa} = \frac{d_a}{2.r_o} .$$

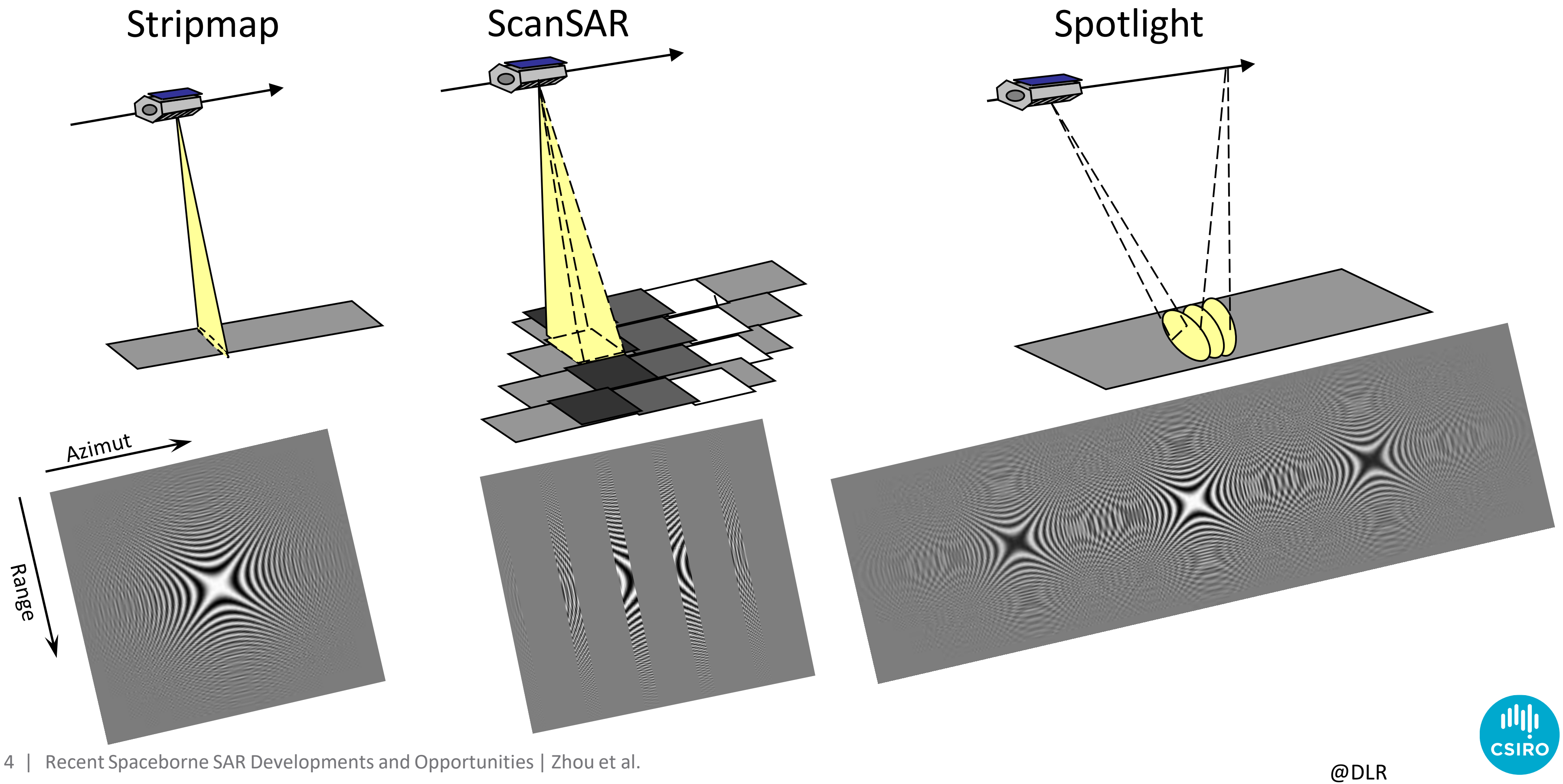
- Azimuth resolution: δ_a

$$\delta_a = \frac{d_a}{2} .$$

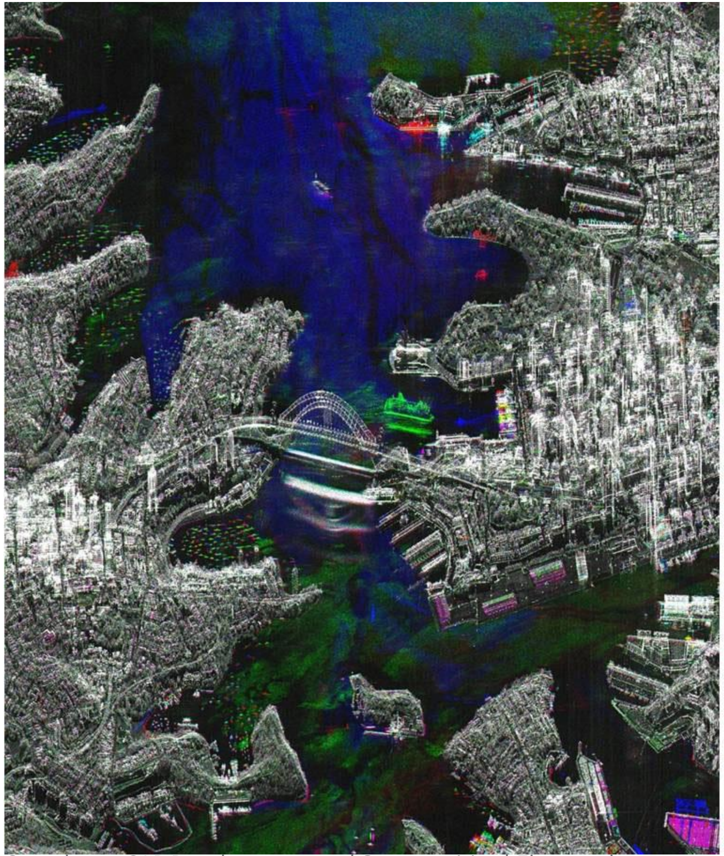
azimuth resolution = half antenna length in azimuth

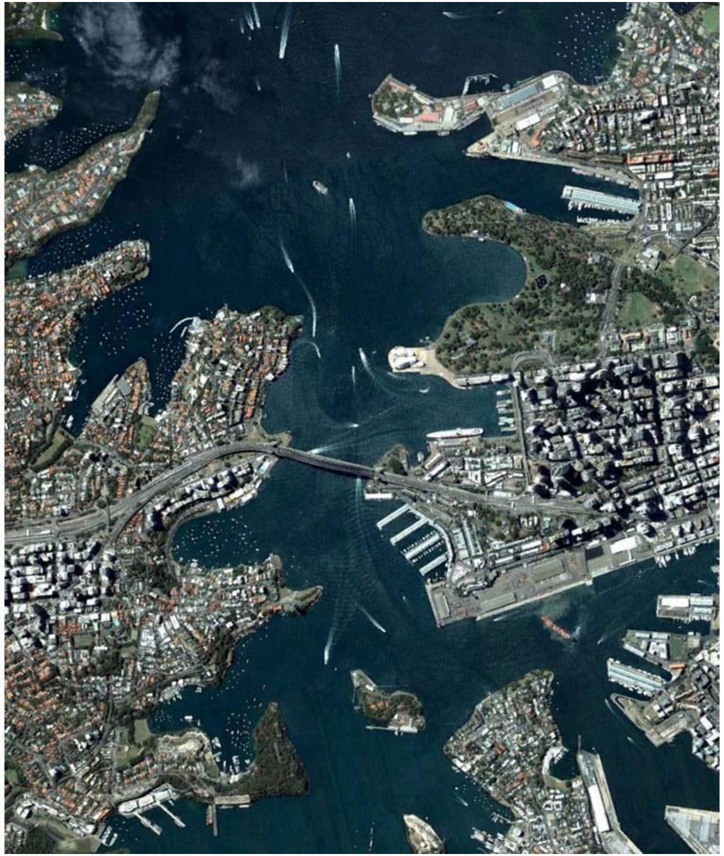
@DLR

SAR Imaging Modes



Sydney: TSX (left, @DLR) and Google Earth (right)



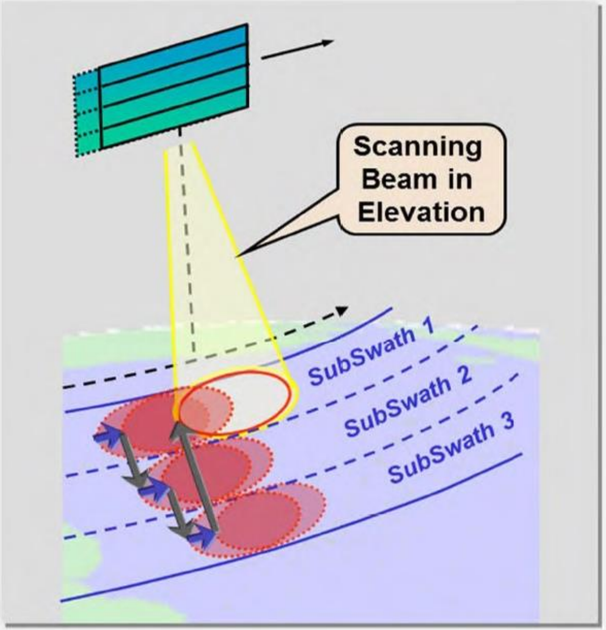


ScanSAR vs TOPSAR (Terrain Observation by Progressive Scan

(Courtesy of Moreira)

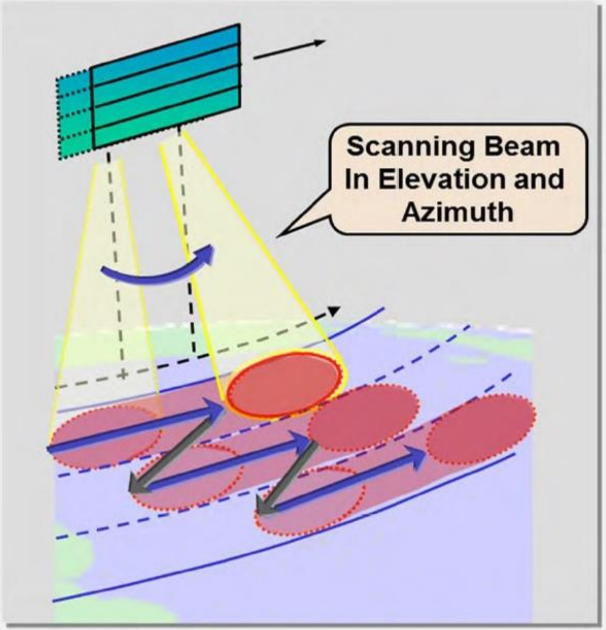
ScanSAR

- Shares illumination time between multiple swaths



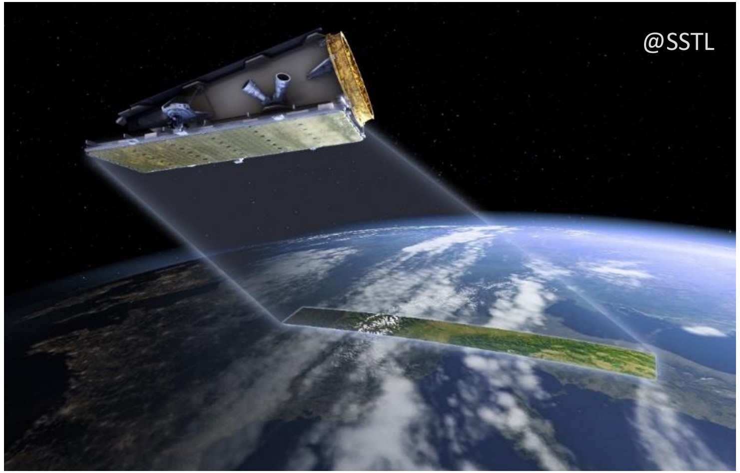
TOPS-SAR

- Shares illumination time between multiple swaths
- Improved image quality



NovaSAR-1 National Facility: CSIRO 10% Share of Mission Capacity

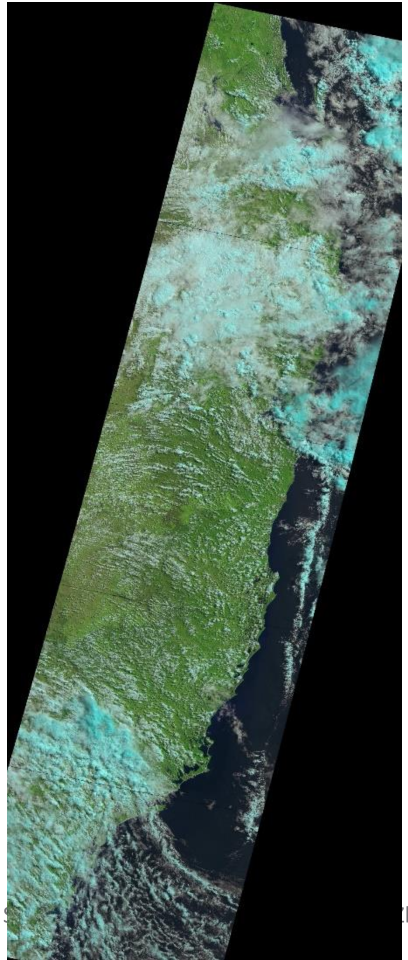
- Low-coast satellite with S-band SAR (4 modes) and AIS payloads by SSTL, UK
- Launched in Sept 2018 with 7 year life time
- Payload duty cycle: 2 min per orbit
- Repeat cycle: 16 days
- CSIRO acquiring 10% of the satellite operational capacity under a partnership

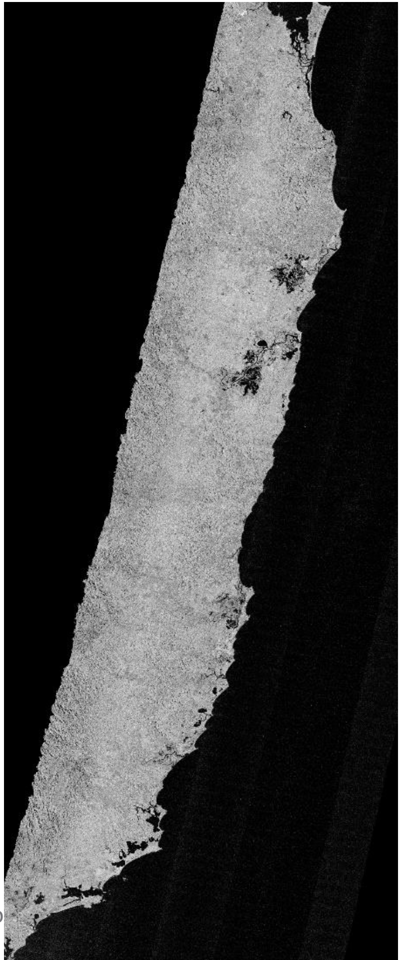


Mode	Swath width	Resolution
ScanSAR mode	50 km & 100 km	20 m
Maritime mode	400 km	6 m across track, 13.7 m along track
Stripmap mode	13 - 20 km	6 m
ScanSAR wide mode	55km, 100km, 150 km & 195km	30 m, 35m or 45m

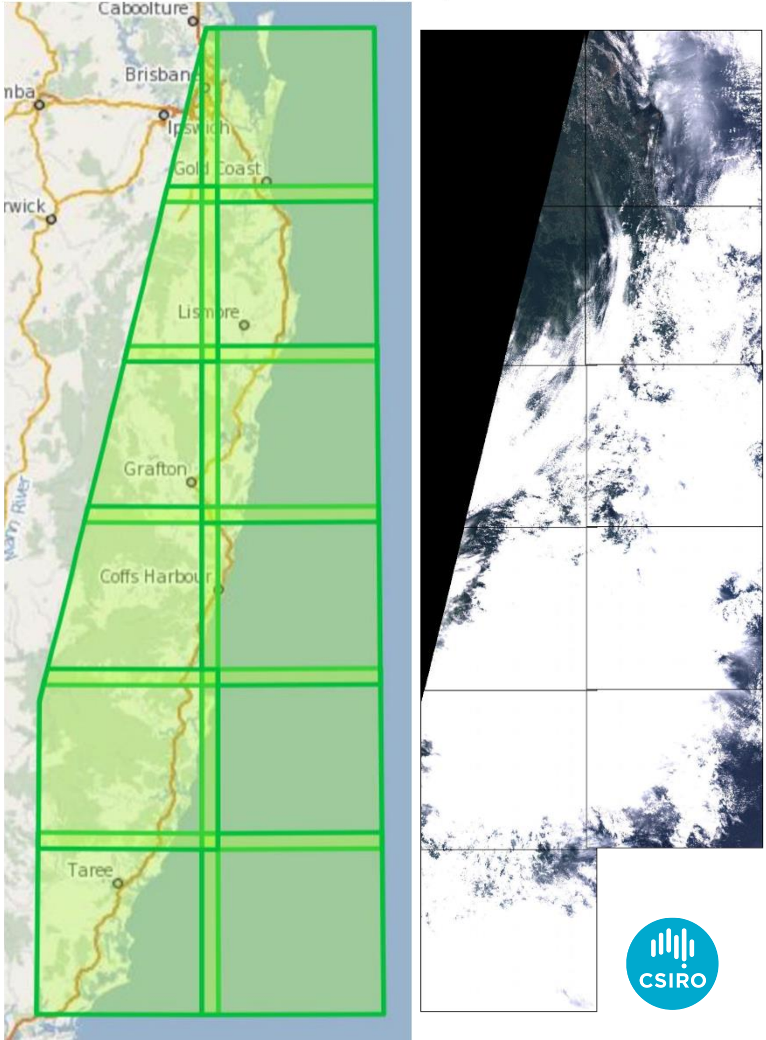
2022 Eastern Coasts Floods in early March

Observations by
Landsat-8 on 3 Mar (left)
NovaSAR-1 on 5 Mar (centre)
Sentinel-1 on 6 Mar (right)





Sentinel-2A Scene Coverage and Images acquired at 20220306T235251 UTC

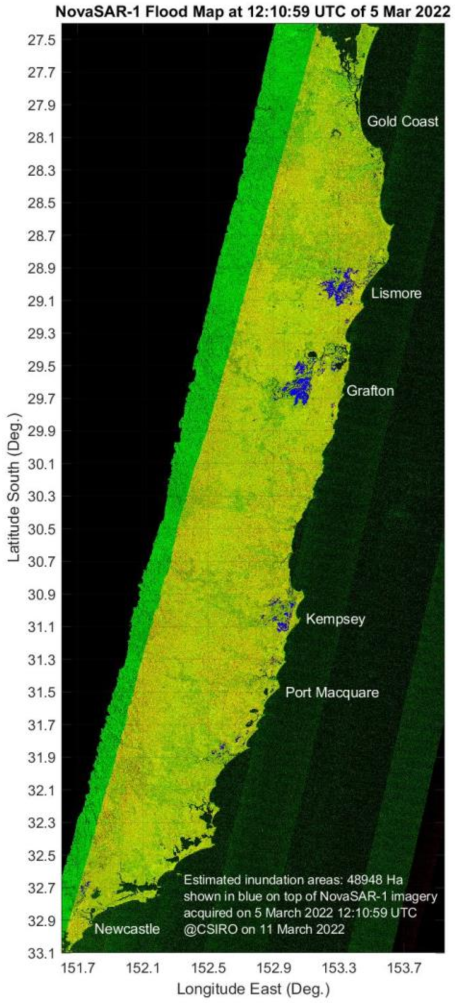


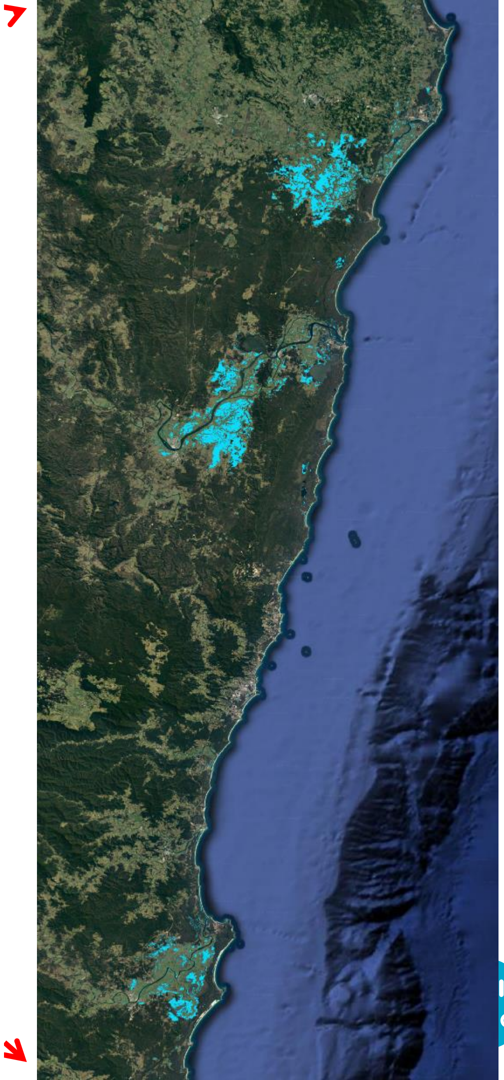
Products of Floods M
using NovaSAR-1 Ima

Flooding extents map on top of NovaSAR-1 image (left) and shapefile on Google Earth (right)

According to NRRA, our products are more accurate than one by th third party

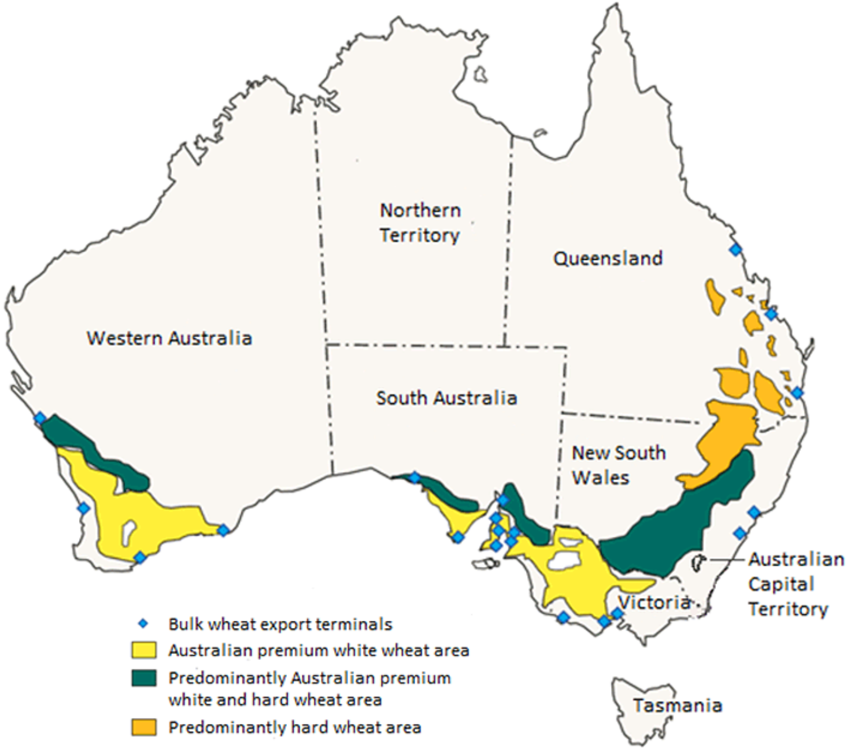
(Work with C Ticehurst of L&W and A Parker of S&A under Space FSP SAR project)



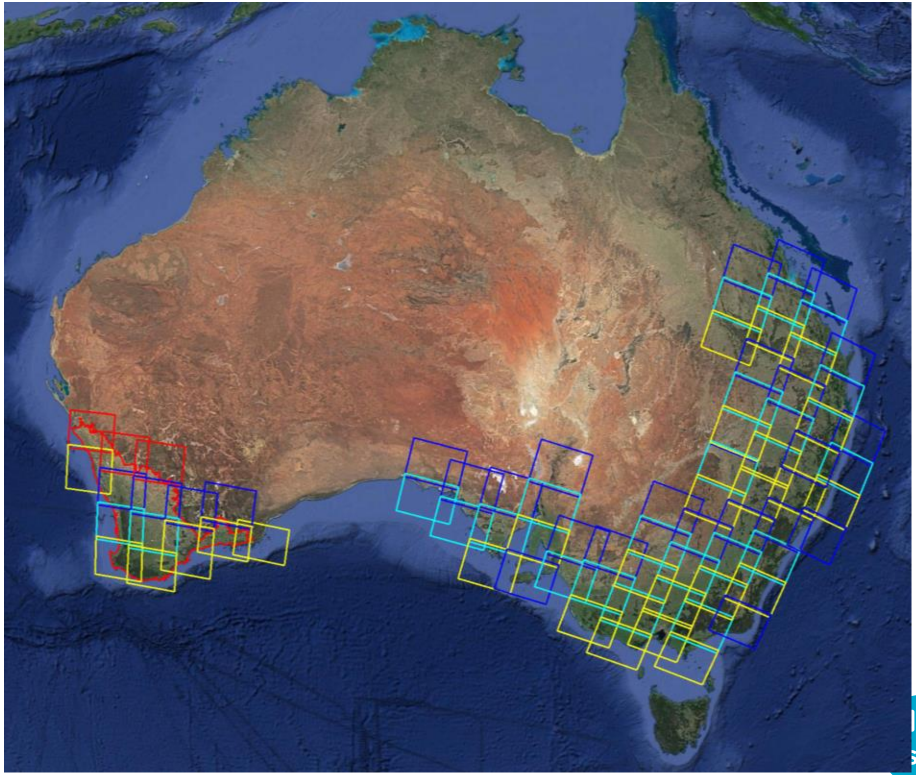


Provision of Sentinel-1 Time Series Making National-scale Crop Mapping Possible

Wheatbelts in Australia (left) and Sentinel-1 Data Coverage (right)

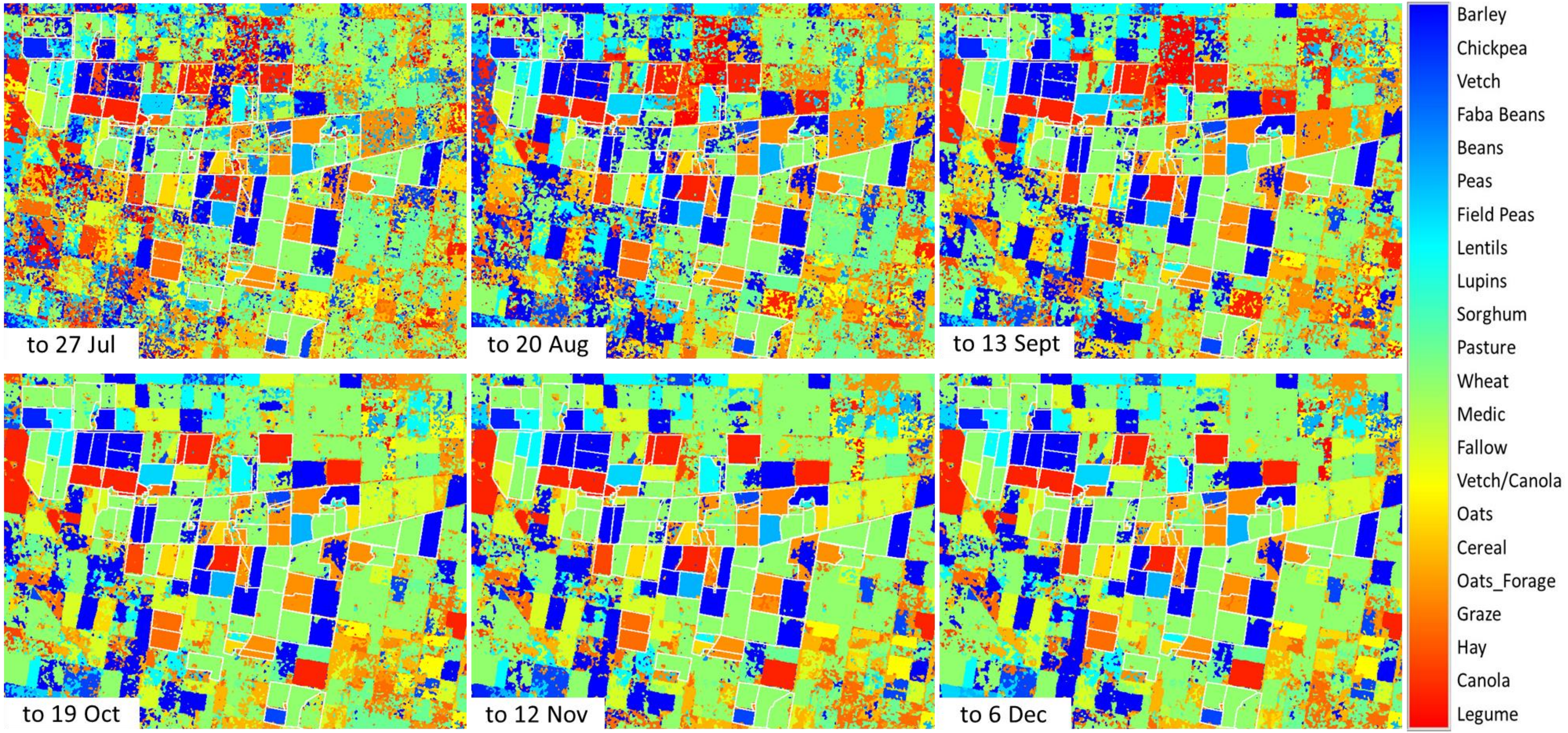


Source: ABARES



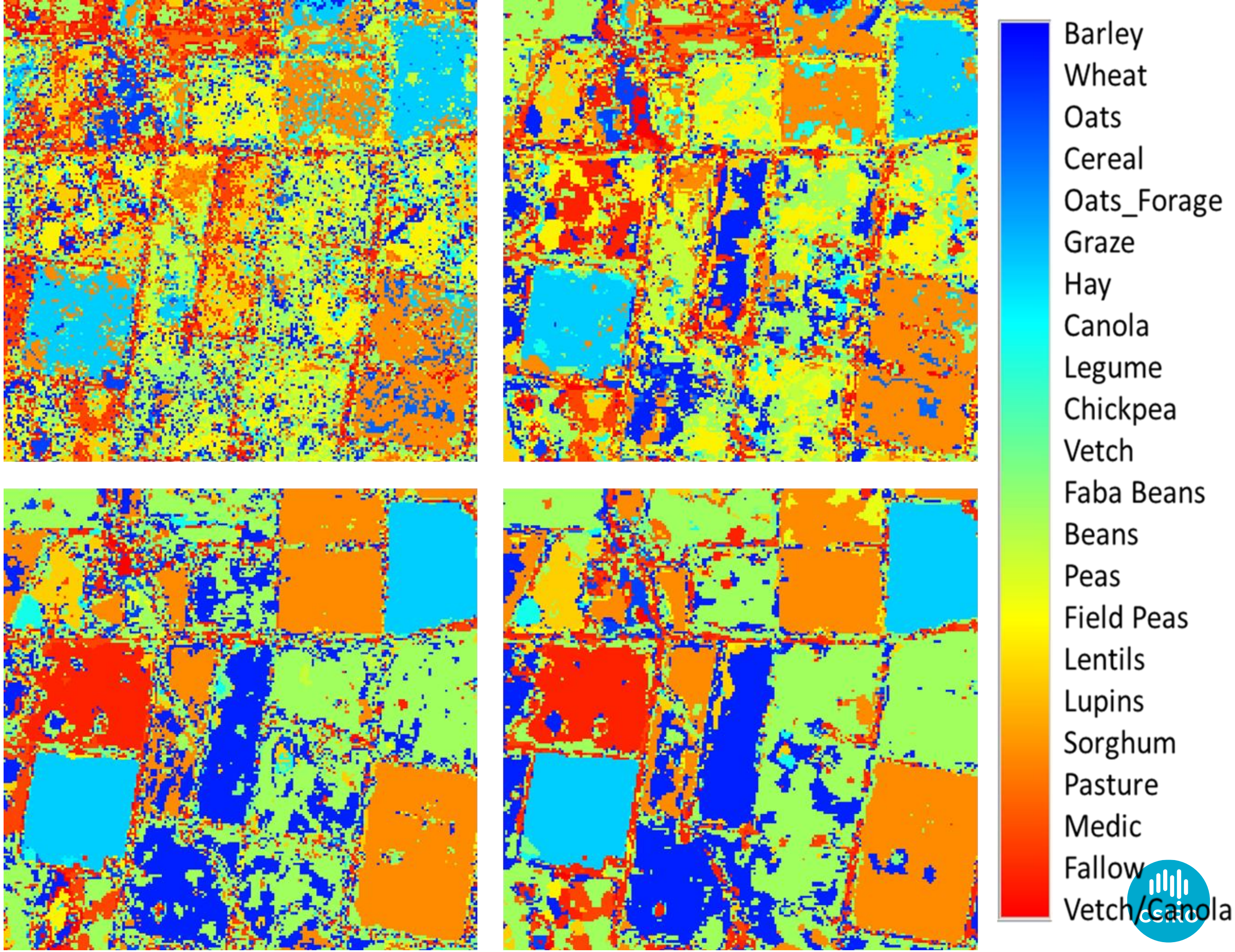
How Sentinel-1 Time Series Improving Crop Mapping Accuracy - Example in VIC 2016

Crop Map (21.9km x 16.8km approx.) Derived from First 5 Dates (top left), 7 Dates (top middle), 9 Dates (top right), 12 Dates (low left), 14 Dates (low middle) and 15 Dates (low right) of Sentinel-1 Time Series over the 2016 Growing Season



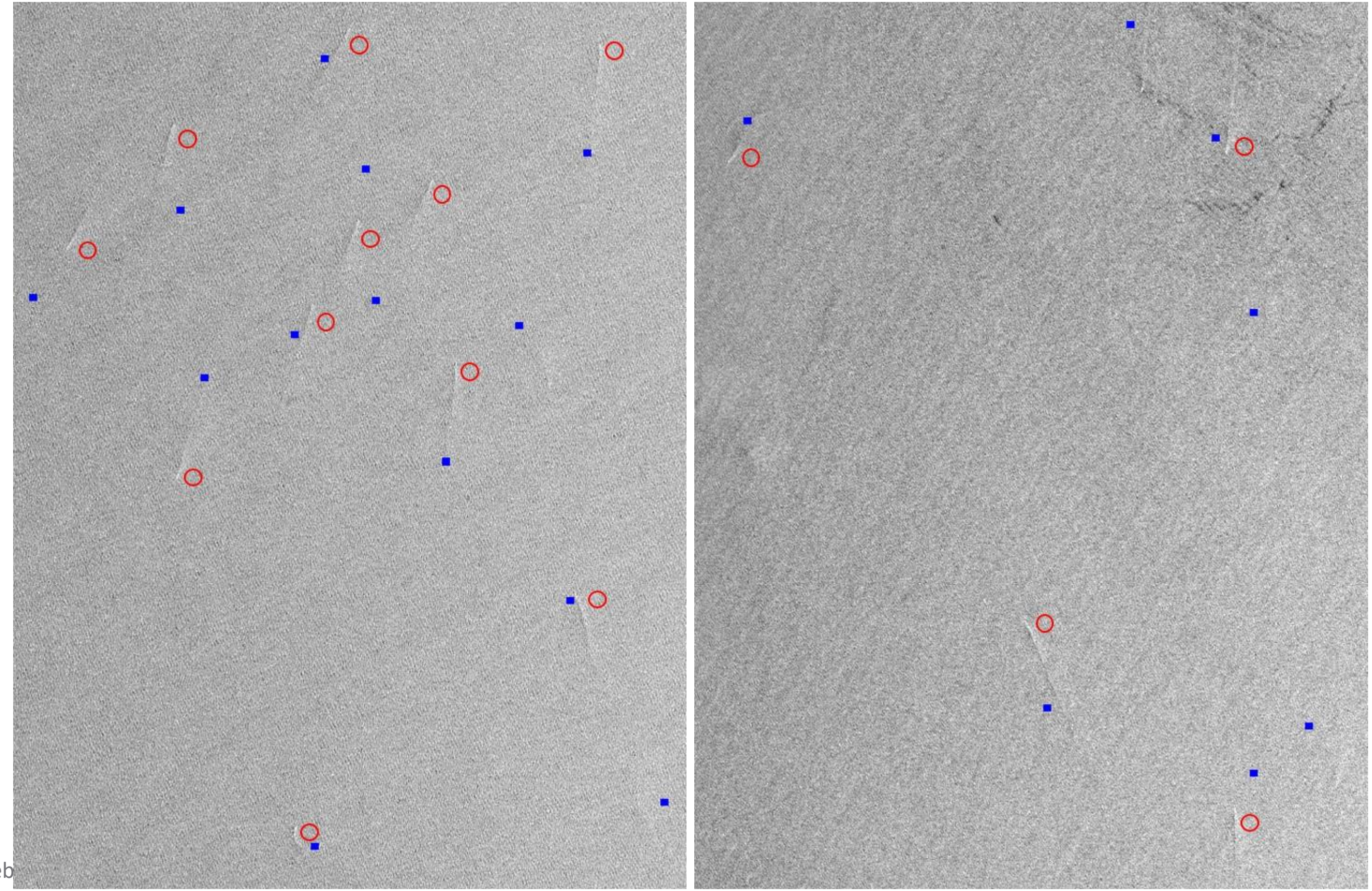
Improved Crop Type Classification by Polarimetric Analysis of ALOS-2 Dual-pol Data

Crop Map 1 (5.1 x 5.0 sqkm) around Birchip, Victoria:
single date 20160710 HH+HV (top left),
single date 20160710 HH+HV+H+a+A (top right),
single date 20160918 HH+HV+H+a+A (bottom left)
and two-date 20160710+0918 HH+HV+H+a+A (bottom right)



(Zhou et al, 2019)

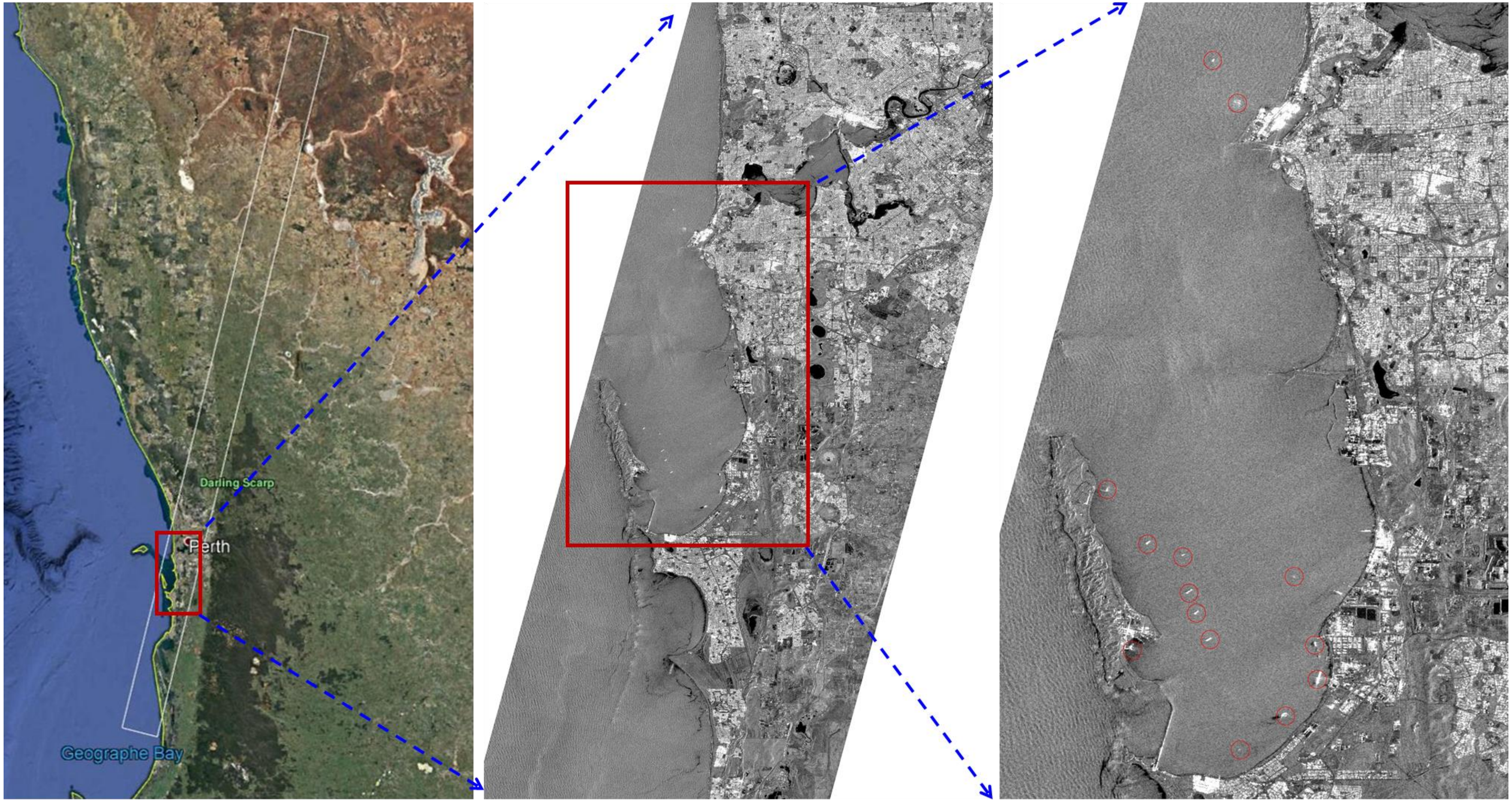
Fishing Vessel Detection in Gulf of Carpentaria: TSX StripMap Mode (Left) and ScanSAR Mode (Right), the red circles indicate the candidates of detected fishing vessels with +/-30min VMS Info in blue dots



Trial of Ship Detection using NovaSAR-1 Imagery

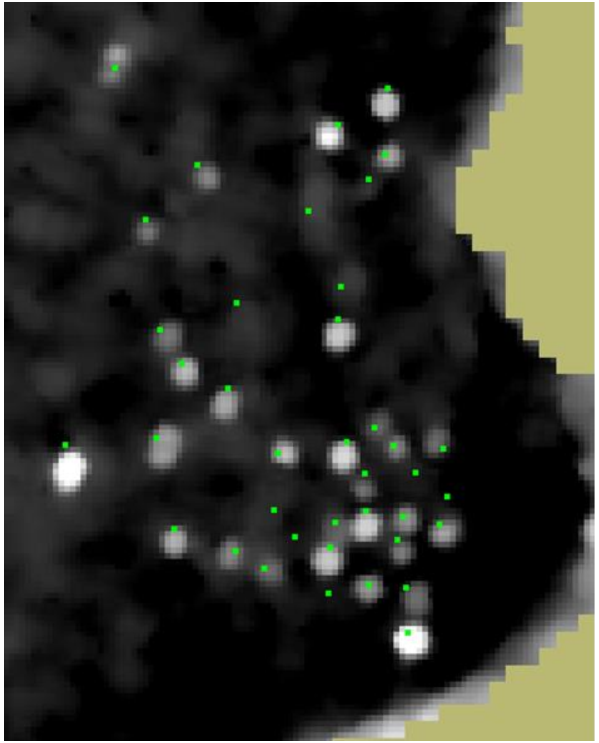
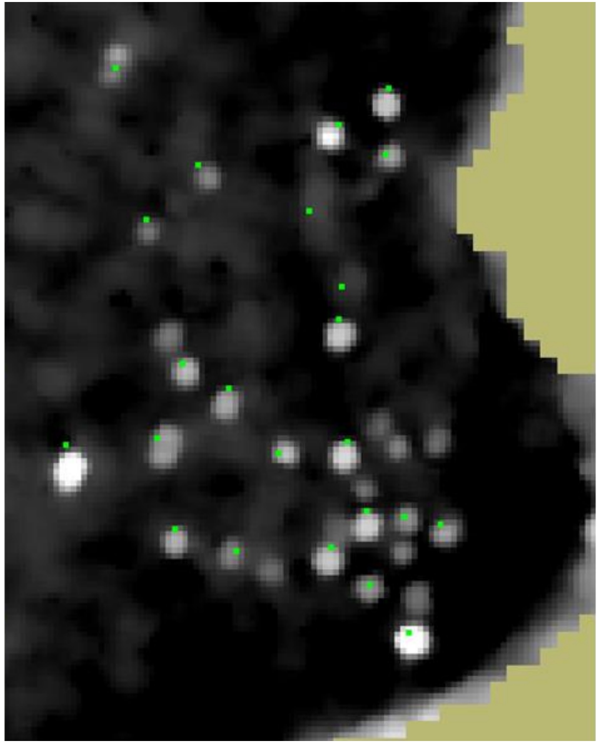
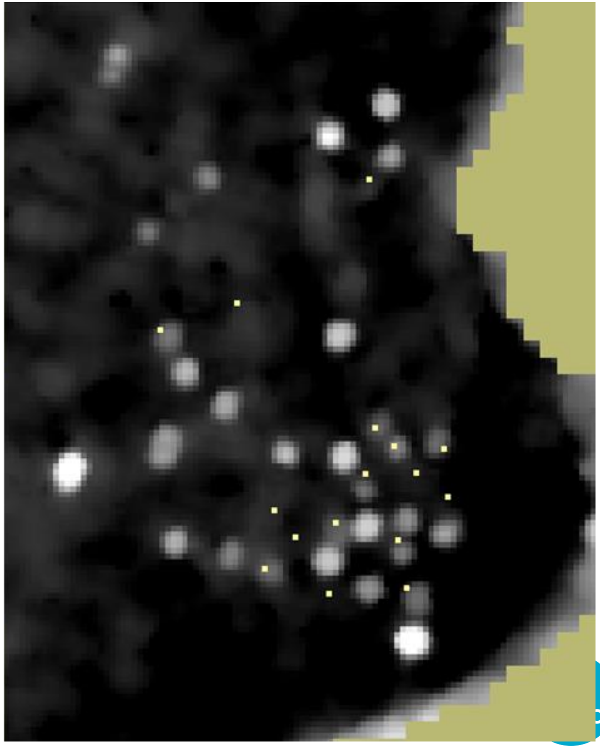
(Under the Space FSP SAR project of CCEO)

Ship Detection by NovaSAR-1: Scene footprint of NovaSAR-1 SCD image acquired on 4 July 2020, HH image of Perth Coast (centre) and Detected ship candidates in red circles (right)



Vessel Detection Results on top of Sentinel-1 Images in Horseshoe Bay, northern side of Magnetic Island, QLD:

39 Labelled vessels provide by GBRMPA (left), 23 Detected vessels combining VV and VH results (centre) and 16 Undetected vessels (right).

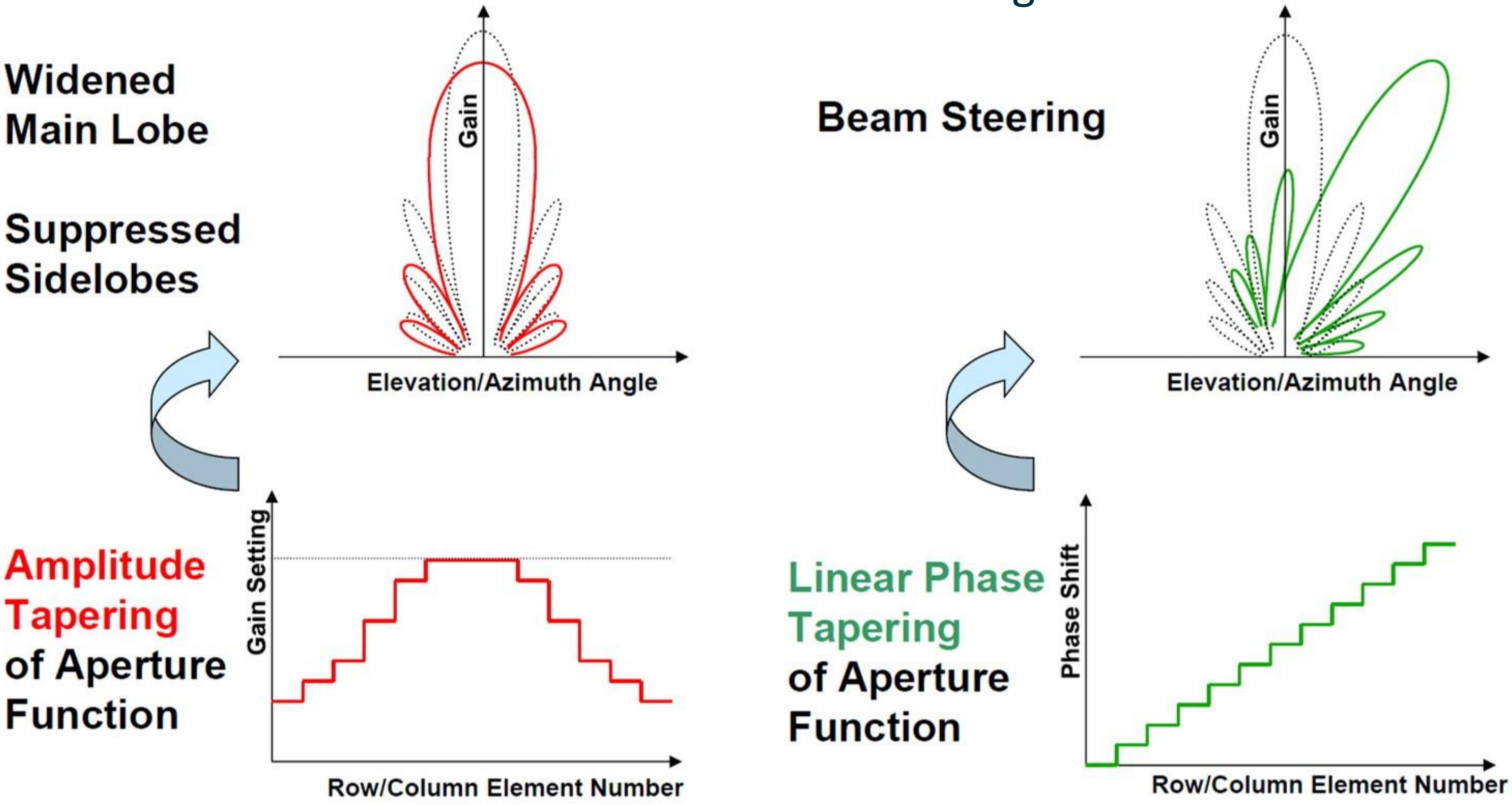
Vessel Detection Probabilities by Sentinel-1 IW Image (20m resolution) in Horseshoe Bay, QLD on 7 June 2022

Vessel Class	Vessel Number	Detected Vessel Number	False Detected Number	Detection Probability	False Detecting Probability
All	39	23	0	58.97%	0
Long than 15m	6	6	0	100.0%	0
Long than 12m	22	16	0	72.73%	0
Long than 10m	30	20	0	67.67%	0

Advanced SAR Techniques

(Courtesy of Moreira)

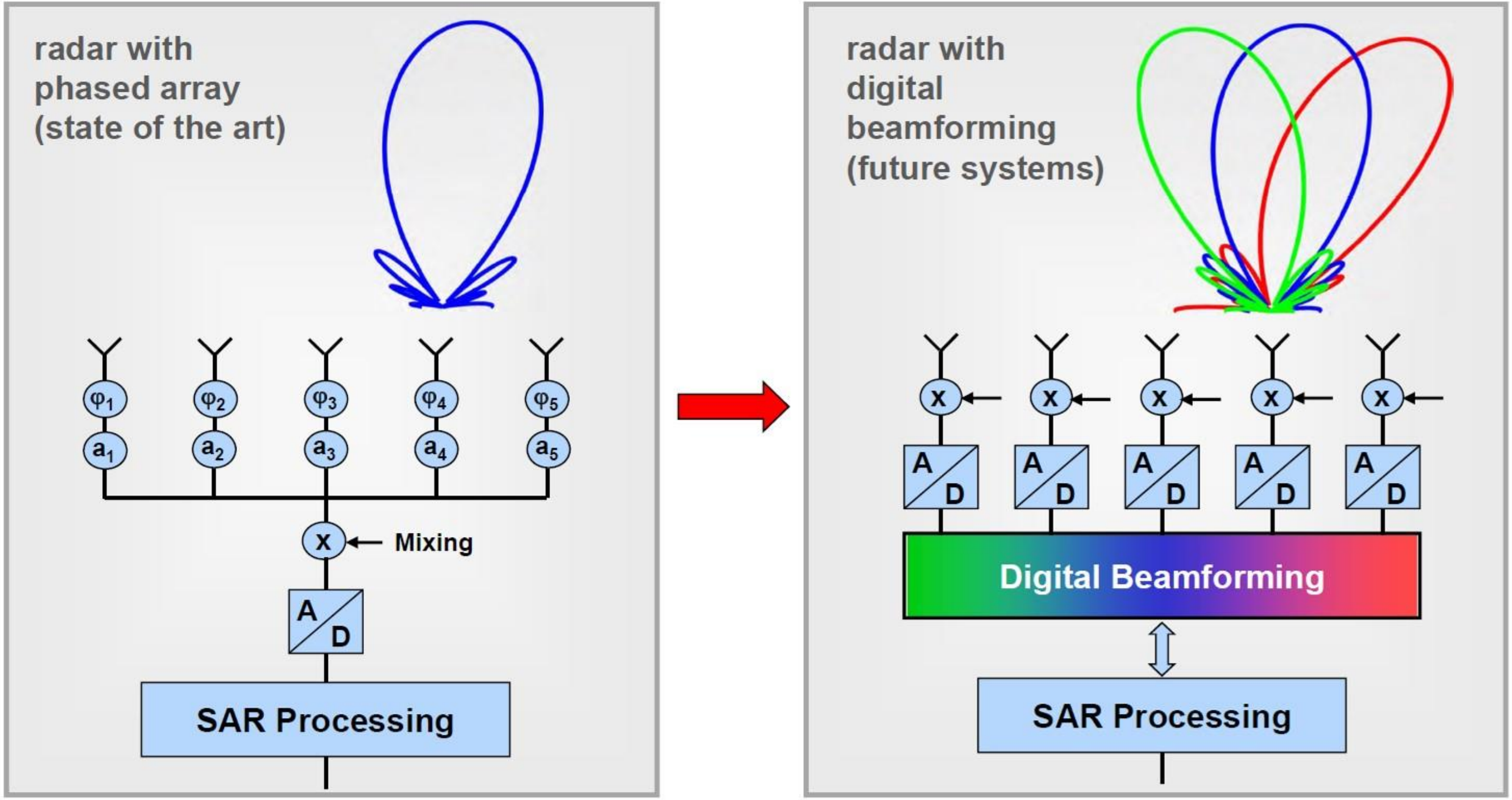
Electronic Beamforming



Digital Beamforming

– New technologies make wider imaging extent possible without loss of resolution and quality

(Courtesy of Moreira)



Forthcoming Major SAR Missions

According to CEOS, 400+ EO satellites in next decade with more than half of SAR sensors

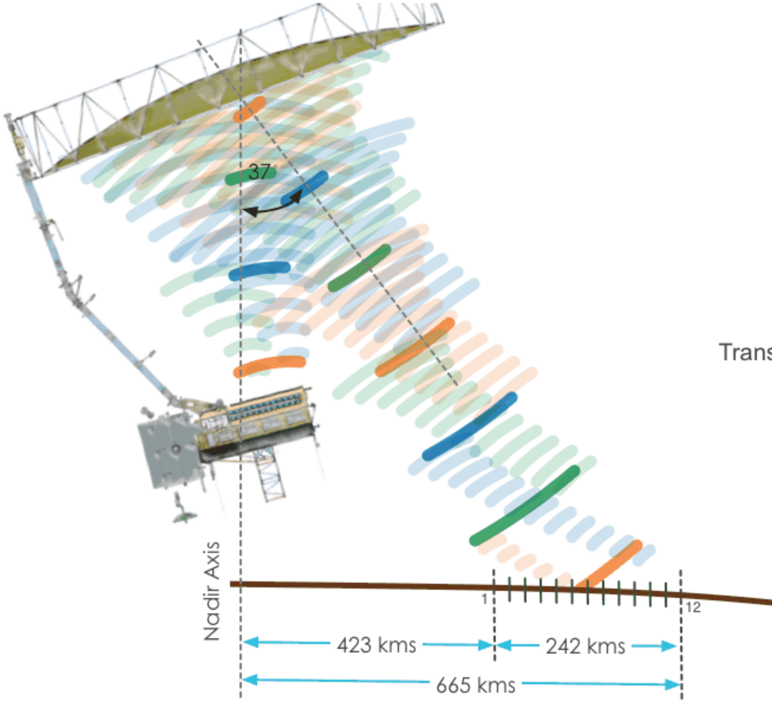
- L and S- band NISAR (2023) by NASA & ISRO
- P-band BIOMASS (2023) by ESA
- L-band ALOS-4 (2023~) by JAXA
- C-band Sentinel-1 C/D (2023~) by ESA
- L-band ROSE-L (2028) by ESA
- X-band MirrorSAR (HRWS) (2030) by DLR and Airbus DS
- L-band TanDEM-L (2030~) by DLR
- C-band Sentinel-1 NG (2032~) by ESA

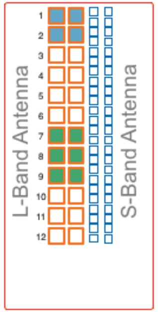
NISAR Spacecraft

(Image Credit: Airbus DS)

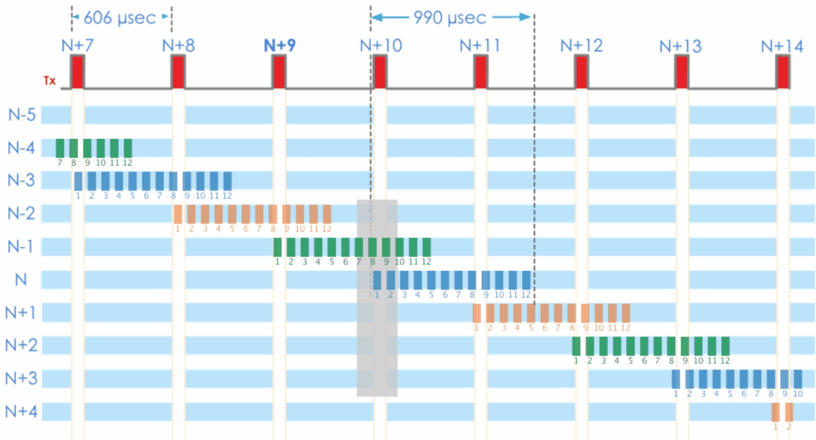
NISAR’s Instrument: SweepSAR

@NASA JPL





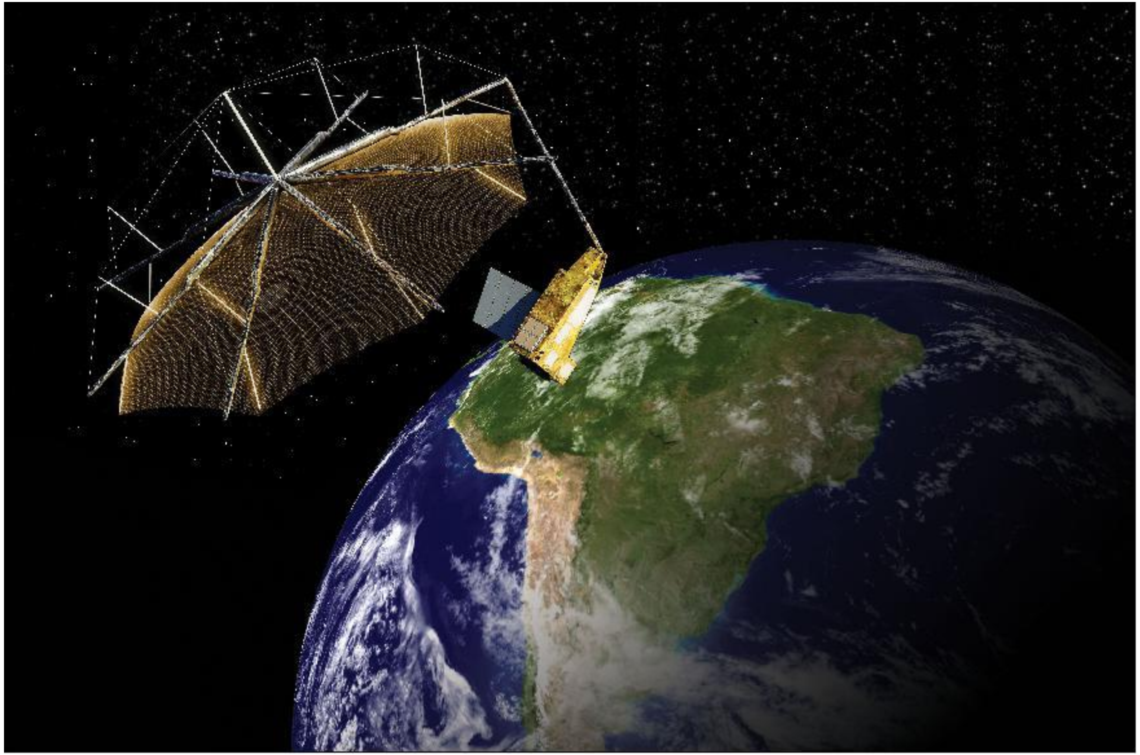
Transmit / Receive Event



PRF = 1650 Hz, PRI = 606 µsec.

Echo time difference between 423 km to 665 km swath = 990 µsec

BIOMASS Mission – a Game Changer in Forestry (Image Credit: Airbus DS)



Primary Objectives: determination of

Forest biomass

Forest height

Vegetation disturbances and re-growth

Secondary Objectives:

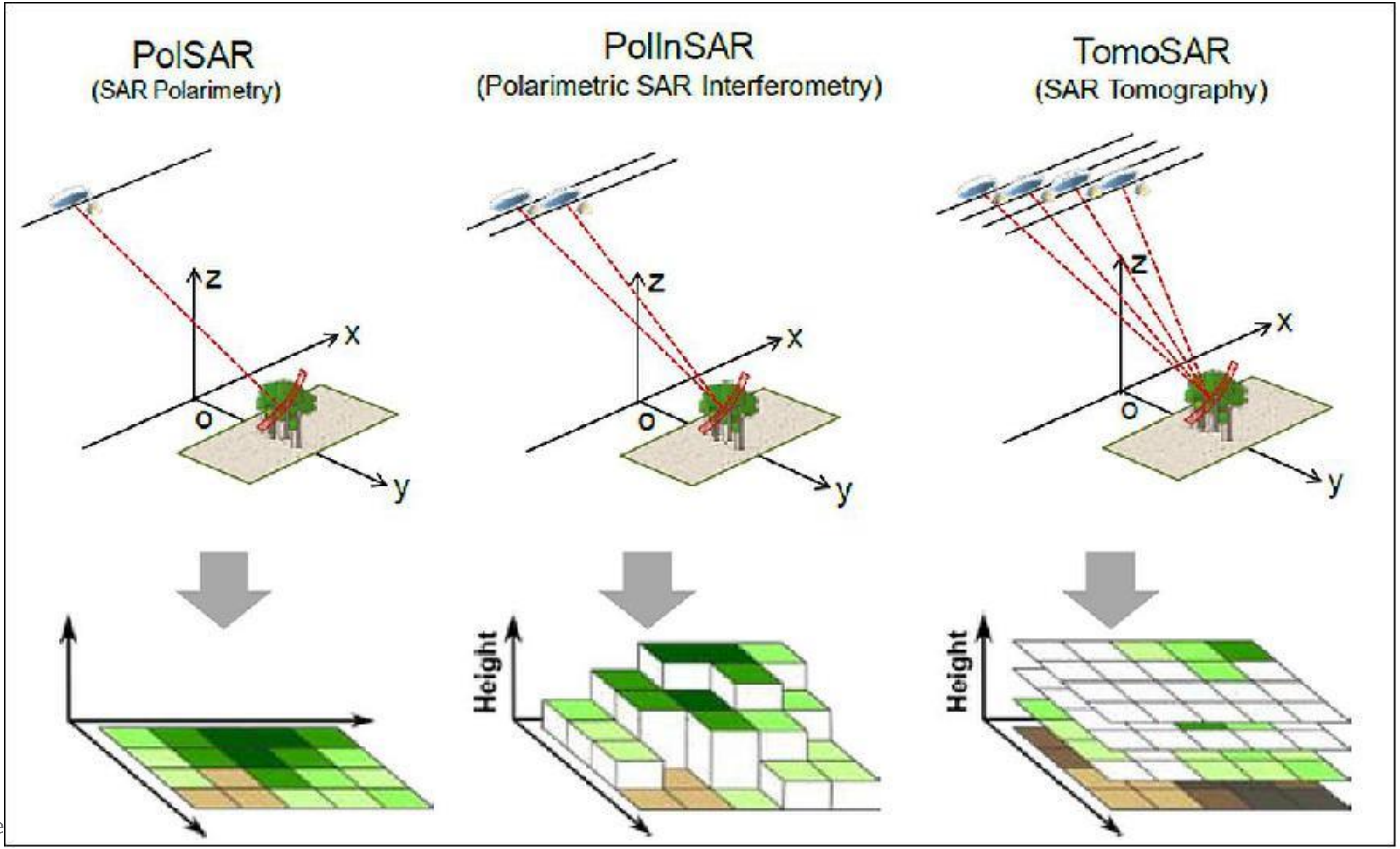
Imaging of sub-surface geology in deserts

Mapping the tomography under dense vegetation

Measurements of glacier and ice sheet velocities

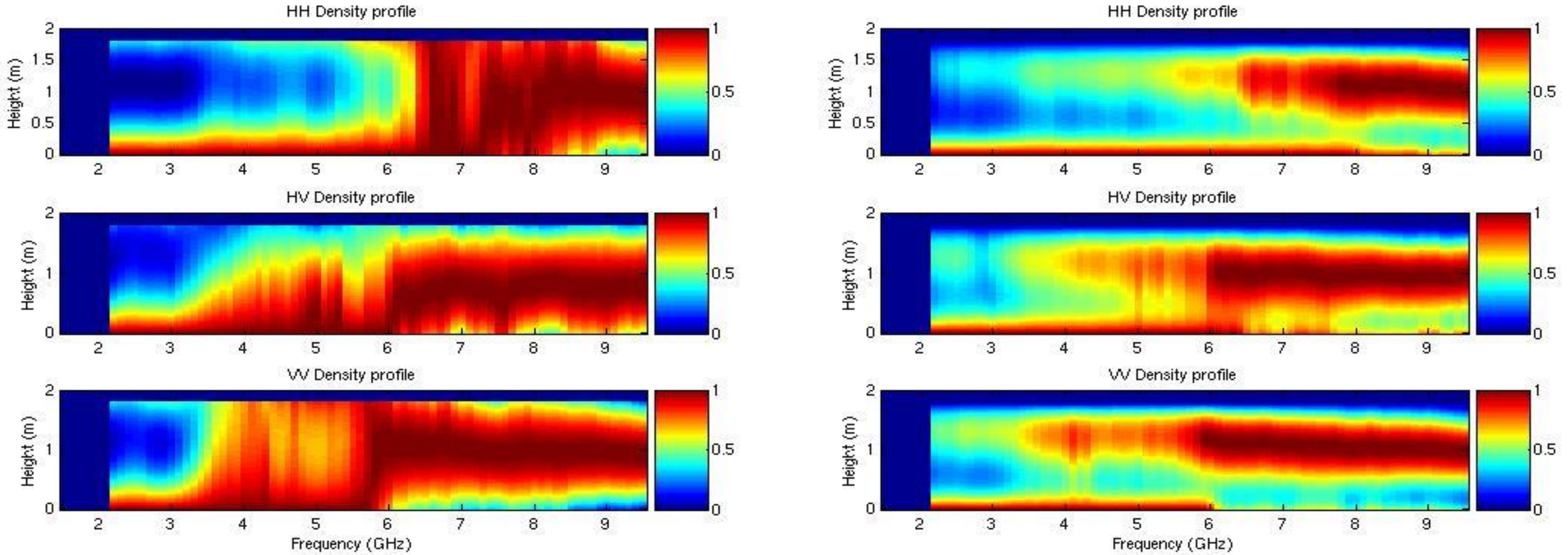
BIOMASS Observation Principles

(Image Credit: ESA)



Single vs Dual Baseline Vertical Tomograms

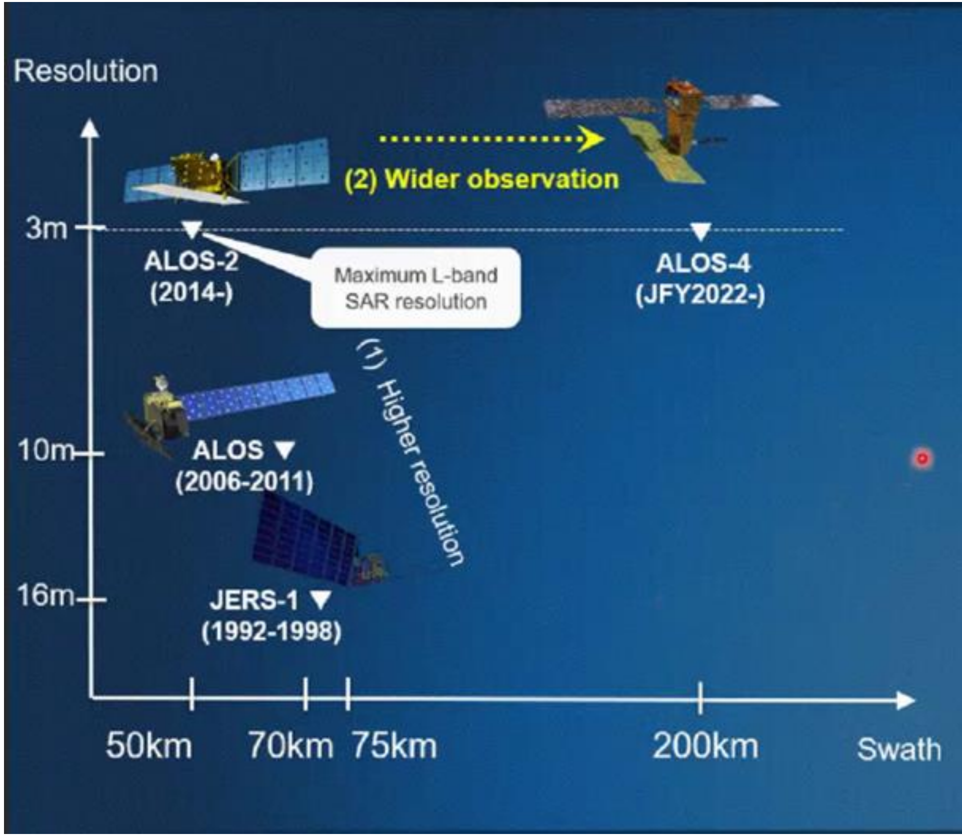
-- JRC EMSL PolInSAR Maize Experiment

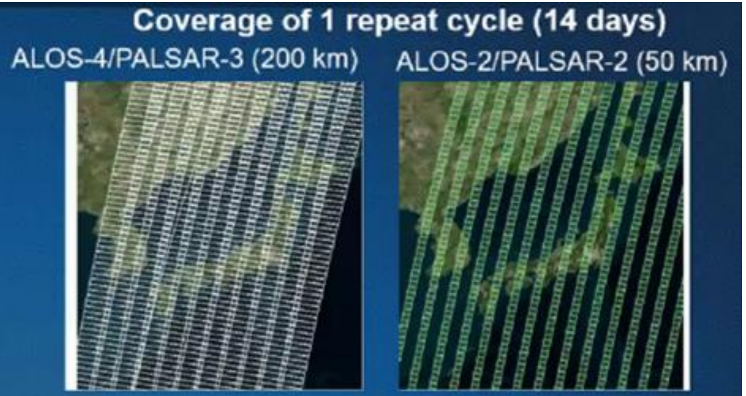


N.B the scattering profiles are not exponential
…can also help explain some of the problems with PolInSAR inversion for this data set

@UoA

JAXA's Continuous L-band Observations & ALOS-4



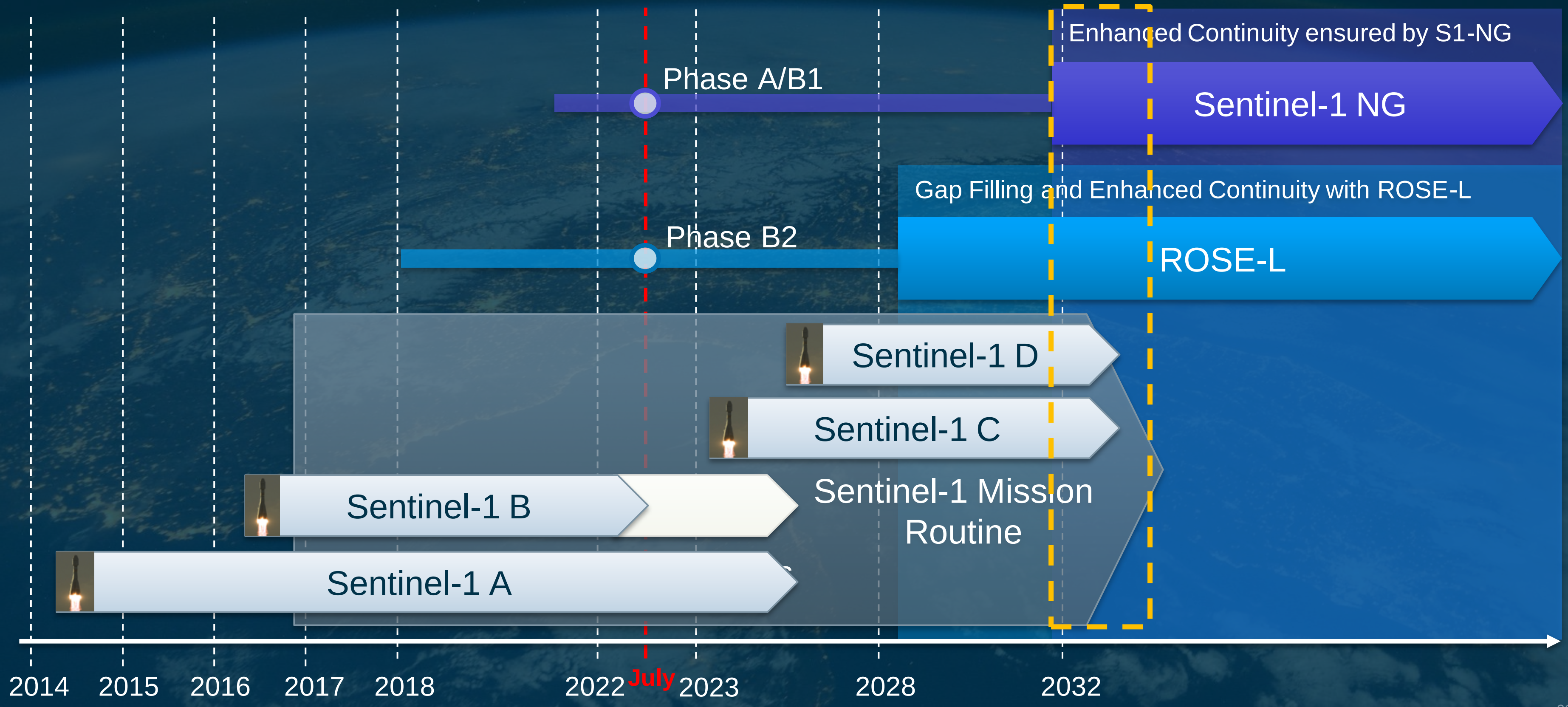


Swath width of PALSAR-3/2

Modes	PALSAR-3	PALSAR-2
Stripmap (res. 3/6/10 m)	100-200 km	30-70 km
ScanSAR (res. 25m*)	700 km	350-490 km
Spotlight (res. 1 x 3 m)	35km×35km	25km×25km

*single look

Copernicus SAR Missions – Long Term Scenario



What is coming next?
HRWS MirrorSAR Mission

Main applications:
High-Resolution Wide-Swath Imaging and High-Resolution DEM

Cheap Rx-only S/C:
- transponder-like
- no full radar receiver
- avoids/simplifies radar control and timing units
- no memory, no downlink
- low power, lightweight

MirrorSAR Iluminator:
- HRWS satellite enables a cost efficient implementation of the MirrorSAR concept

Josef Mittermayer, Gerhard Krieger, Allan Bojarski, Mariantonietta Zonno, Michelangelo Villano, and Alberto Moreira, A MirrorSAR Case Study Based on the X-BandHigh Resolution Wide Swath Satellite (HRWS) , Proceedings of EUSAR 2021

More Opportunities

L-band SAOCOM-1A/B by CONAE
https://www.argentina.gob.ar/ciencia/conae/misiones-espaciales/saocom

Low cost radar satellite constellations for frequent coverage, e.g., Capella, MicroSAR and ICEYE
https://earth.esa.int/eogateway/catalog/iceye-full-archive-and-tasking

Every Square Meter, Every Hour - ICEYE SAR Satellite Constellation
https://www.youtube.com/watch?v=e8nPu7T0xKE

and more …

Summary

- At "The Golden Age for Spaceborne SAR" (Dr. Alberto Moreira, Director General, Radar Institute of DLR, founder of TSX/TDX), radar remote sensing provides significant potentials for various Earth observation applications.
- SAR tomography allows a real 3-D imaging of volume scatterers.
- Polarimetric SAR Interferometry and tomography allows better interpretation of physical and geometric properties of volume scatters. Microsatellite or a satellite tandem concept can be adopted for efficient realization of this concept.
- Digital beamforming allows the realization of high-resolution wide-swath SAR systems. It is a clear trend for future SAR systems.
- Bi- and multi-static SAR systems in combination with digital beamforming will play an important role for future spaceborne SAR systems.
- Collaborations with agencies and community to utilise Sentinel-1, NovaSAR-1 and other data, and develop credible methodologies for agriculture, forest, environment and marine applications in Australia and our regional countries.
- As Australia's national science agency, CSIRO and its SAR Community of Practice ready to assist you with any radar remote sensing solutions.

Merci Pour Votre Attention

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