@ESA

Polarimetric Processing and Analysis of Sentinel-1 Time Series for State-wide Crop Mapping in Victoria

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Main Challenges for Large-scale Crop Mapping

- Rountine observations without weather restraints

- Genius/optimal data processing

- Sufferient ground sampling data

- Rebust classiffier

- Accurate crop map as early as possible during the growing season

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➢ Large-scale Crop Type Mapping via Classification Propagation

➢ Summary

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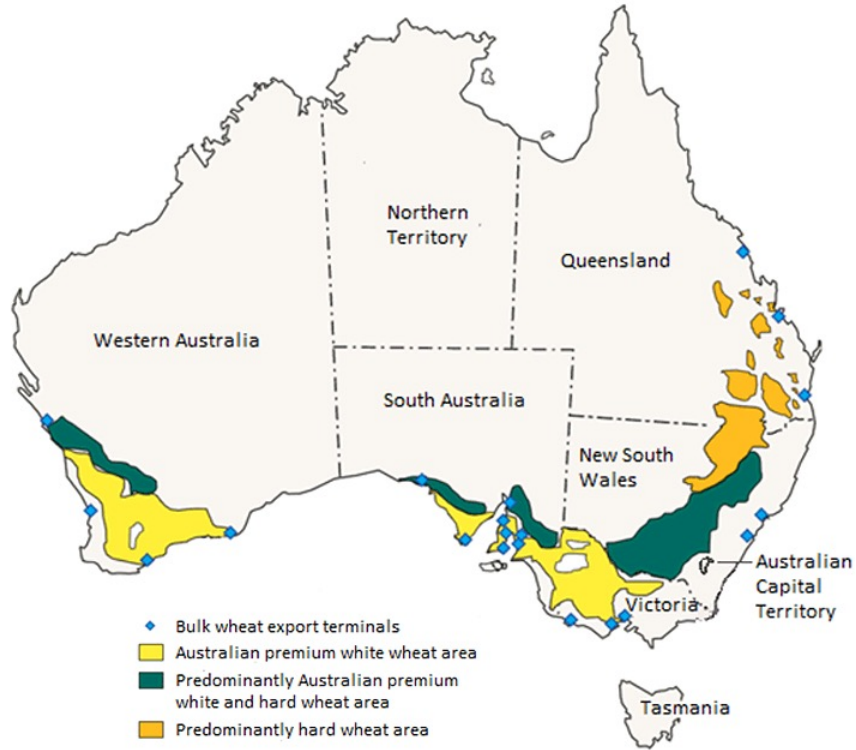

Source: ABARES
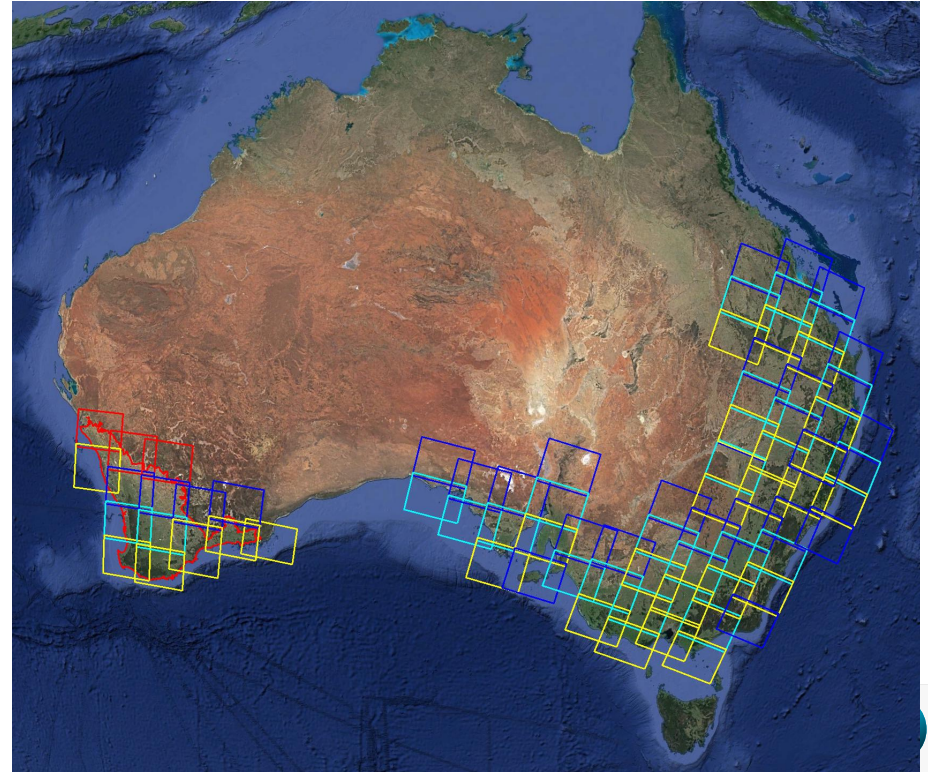
Preprocessing of Sentinel-1 SLC Data

- As the default imaging mode of Sentinel-1 radar sensor, the Interferometric Width Swath mode (IW) dual-pol data are the majority of S1 products (approx. 80% of all S1 products).

- We show evidence how the polarimetric analysis can improve the crop classification accuracy and how early the S1 time series can provide reasonable accuracy of crop type map in state scale.
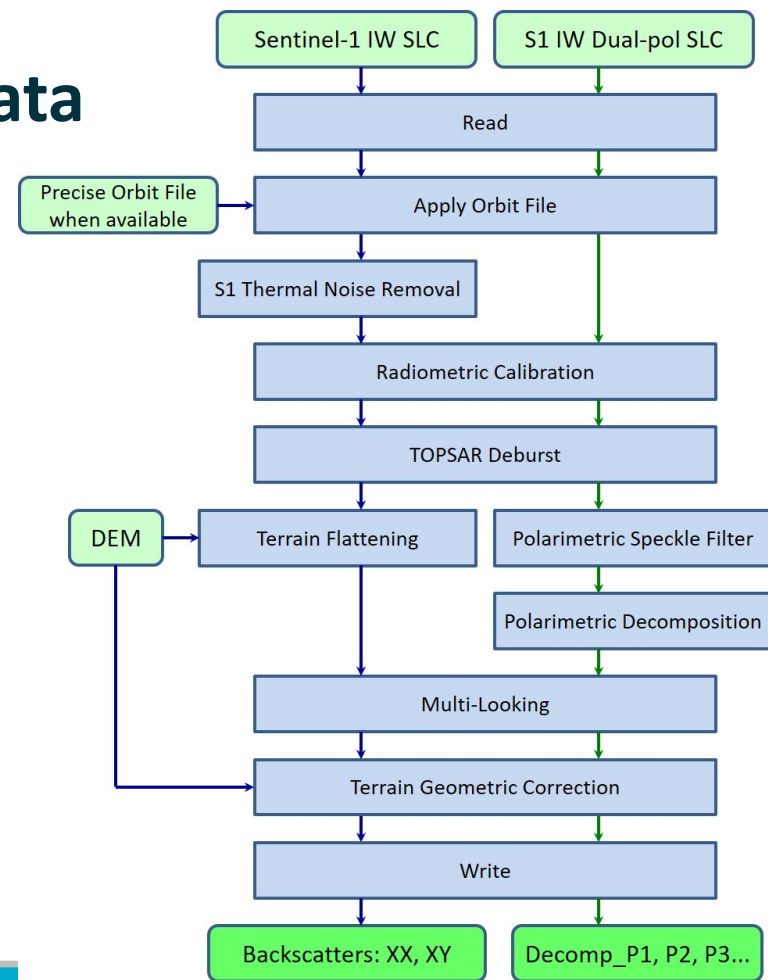
SNAP Graphic Diagram of Sentinel-1 NRB Processing with Thermal Noise Removal and Terrain Flattening
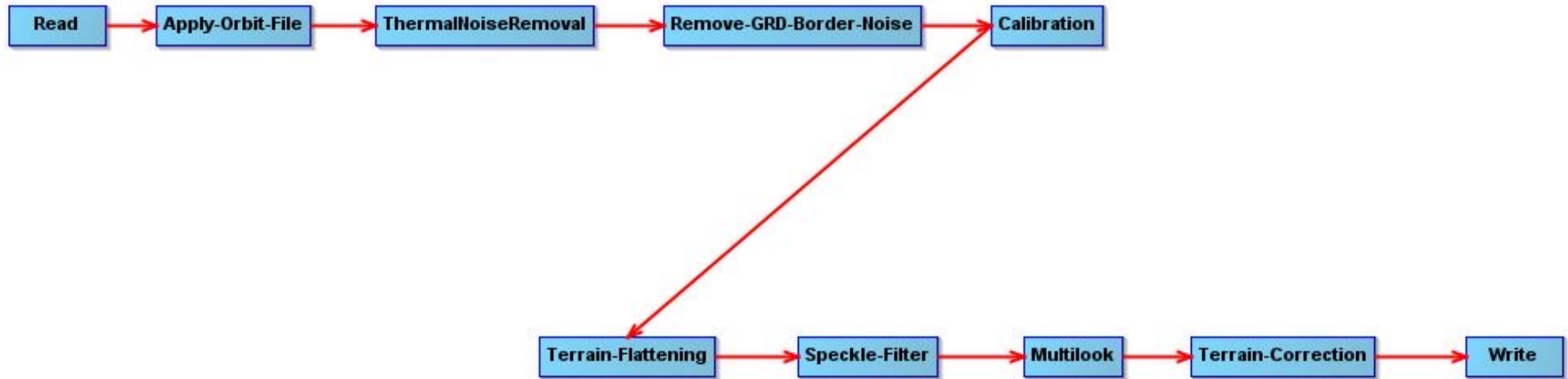
Dual Polarised Entropy/alpha Decomposition for Crop Discrimination

(Cloude, PolInSAR 2007)

Coherent radars can be used to estimate the 2x2 wave coherency matrix

$$[J_H] = \begin{bmatrix} \langle S_{HH} S_{HH}^* \rangle & \langle S_{HH} S_{HV}^* \rangle \\ \langle S_{HV} S_{HH}^* \rangle & \langle S_{HV} S_{HV}^* \rangle \end{bmatrix}$$
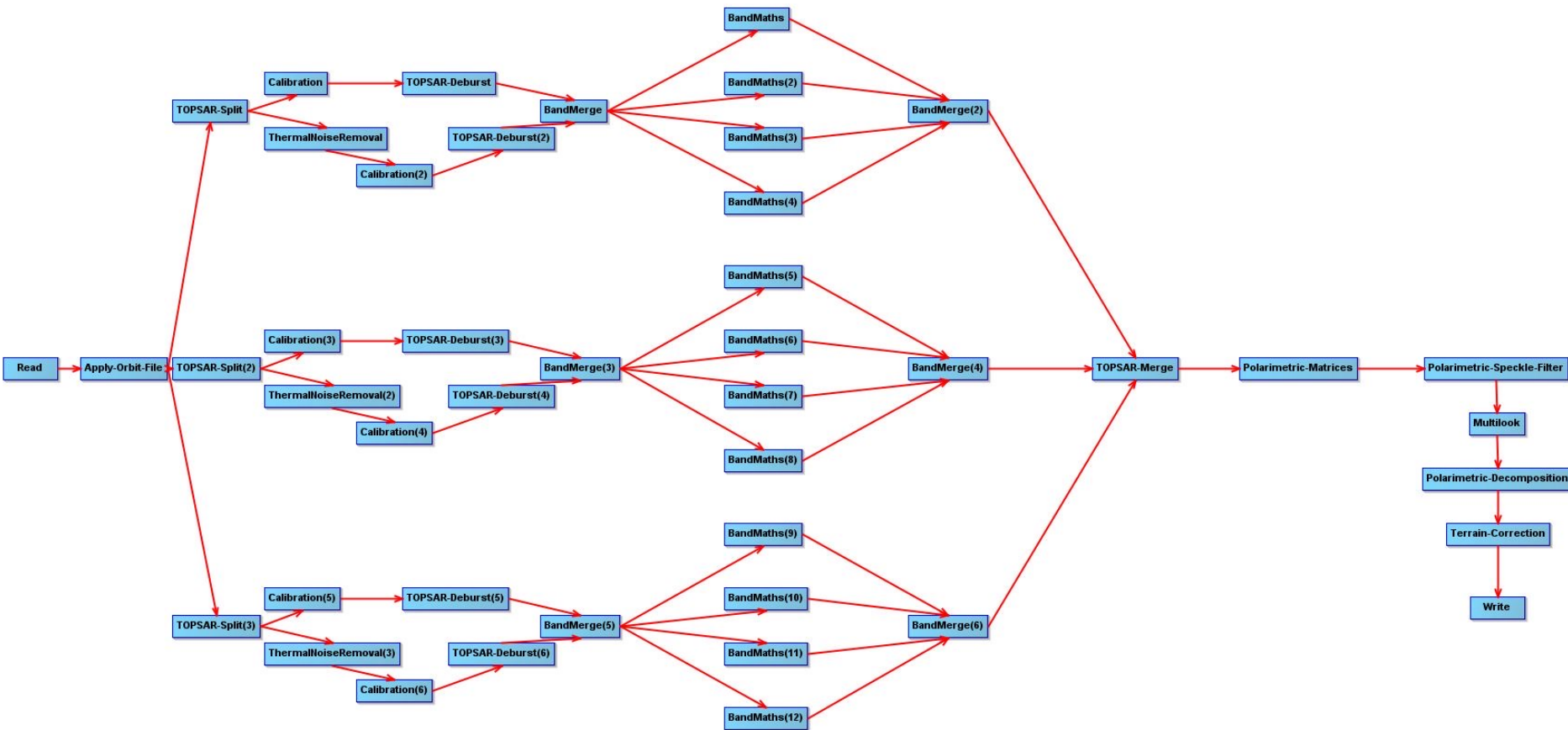
$$[J] = \begin{bmatrix} J_{xx} & J_{xy} \\ J_{xy}^* & J_{yy} \end{bmatrix} \Rightarrow \begin{cases} [U_2] = \begin{bmatrix} \cos\alpha & -\sin\alpha e^{-i\delta} \\ \sin\alpha e^{i\delta} & \cos\alpha \end{bmatrix} \\ [D] = (\lambda_1 + \lambda_2) \begin{bmatrix} P_1 & 0 \\ 0 & P_2 \end{bmatrix} \end{cases}$$

or

$$[J_V] = \begin{bmatrix} \langle S_{VV} S_{VV}^* \rangle & \langle S_{VV} S_{VH}^* \rangle \\ \langle S_{VH} S_{VV}^* \rangle & \langle S_{VH} S_{VH}^* \rangle \end{bmatrix}$$
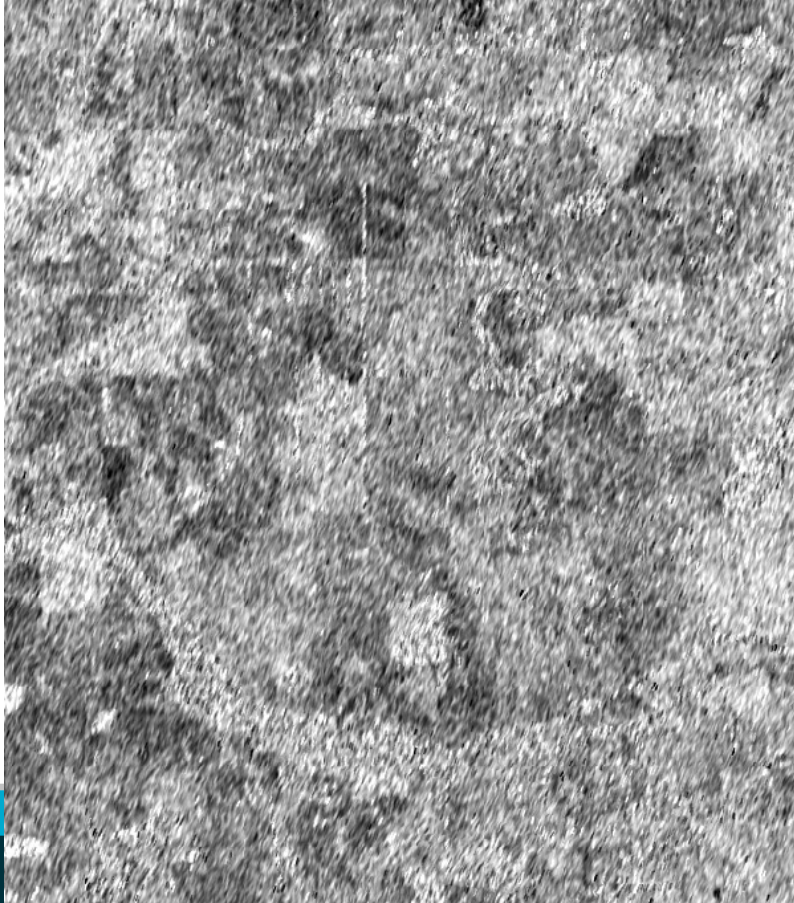
$$\Rightarrow \begin{cases} \overline{\alpha_2} = P_1\alpha + P_2\left(\frac{\pi}{2} - \alpha\right) = \alpha(P_1 - P_2) + P_2\frac{\pi}{2} \\ H_2 = \sum_{i=1}^{2} P_i \log_2 P_i \end{cases}$$

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SNAP Graphic Diagram of Dual-pol Decomposition Processing of Sentinel-1 SLC Data with Thermal Noise Removal (Expansion of Mascolo et al., GRSL 2022)

Comparison of Sentinel-1 Dual-pol Entropy with Noisy (left) and after Noisy Removal (right)

Dual Polarised Entropy/alpha Decomposition for Improved Crop Discrimination

- Wheat is the major winter crop grown in Australia with sowing starting in autumn and harvesting, depending on seasonal conditions, occurring in spring or summer. From the pre-processed whole growing season S1 data stack, one scene acquired in the middle season, i.e., on 8 Aug 2016, from orbit Vic02_orb016, was selected for demonstration.

- Random Forest classifier was applied to 20160808 VH+VV backscatters, and 20160808 VH+VV backscatters & polarimetric scattering angle alpha (a) + Anisotropy (A) + Entropy (H) together with crop sampling data, respectively

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Crop Maps of Two Regions (top row - 2km x 2.5km, bottom row - 6.5km x 8km approx.) derived from 20160808 VH+VV backscatters (left column), and VH+VV backscatters and a+A+H (decomposition analysis from polarization and phase information, middle column) compared to results from 11 dates S1 time series over the whole growing season (right column)

(Zhou et al., IGARSS 2017)
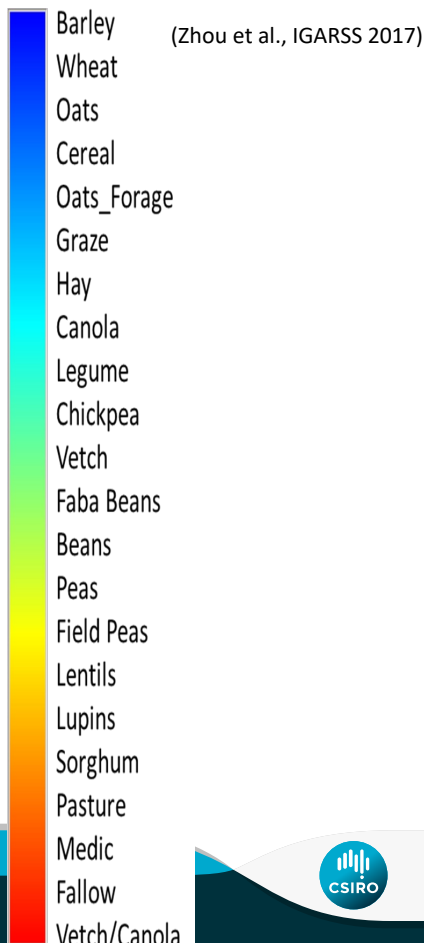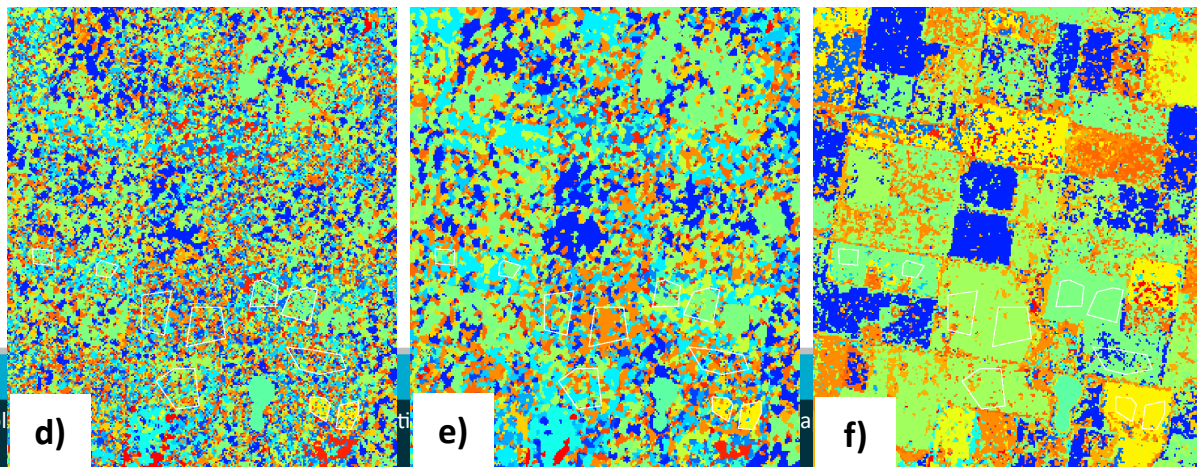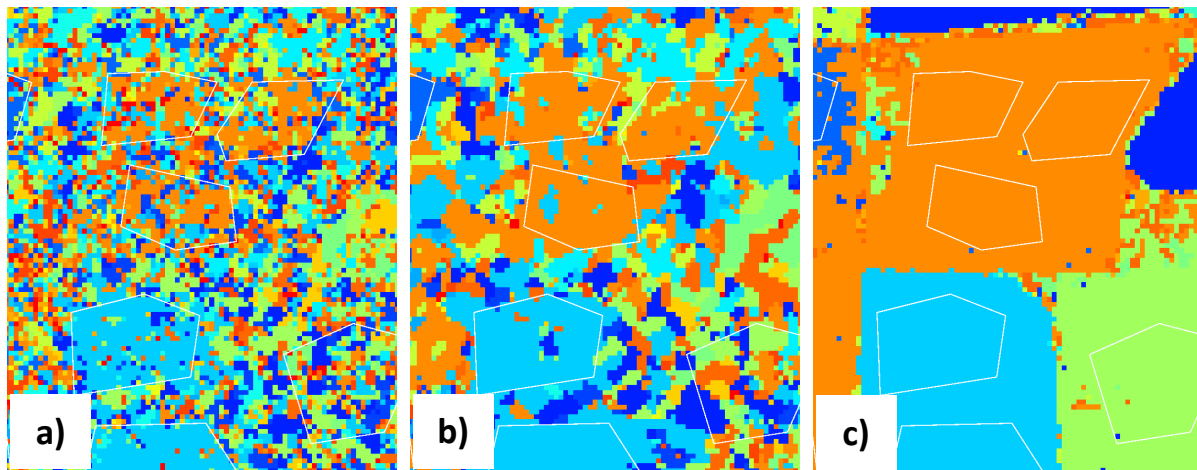
Improved Crop Discrimination with Added Polarimetric Analysis of S1 SLC Data

Crop Discrimination - Separation Score Derived by Various Combinations of Image Bands, as a Percentage of the Total Discrimination Achievable using All Data Simultaneously

(Zhou et al., IGARSS 2017)

Image Band	Separation Score	Percentage of Discrimination
VH	1.204	35.5%
VV	1.147	33.8%
VH+VV	1.809	53.4%
a+A+H	1.862	54.9%
VH+VV+a+A+H	3.390	100.0%

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# Crop Classification in Wheatbelt of Victoria using S1 Time Series

- Wheat is the major winter crop grown in Australia with sowing starting in autumn and harvesting, depending on seasonal conditions, occurring in spring or summer.

- All Sentinel-1A images acquired between April to December 2016 during the crop growing season

- All Sentinel-1 time series up to 15 dates were processed to normalised Gamma0 for both VH and VV and also three polarimetric decomposition products by Eigen based dual-pol decomposition, i.e., alpha (a), Anisotropy (A) and Entropy (H) by above SNAP workflows

- Images acquired on the same date for each orbit were mosaicked and formed 5 data stacks

- Random Forest classifier was applied to each data stack with corresponding training dataset for crop map

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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
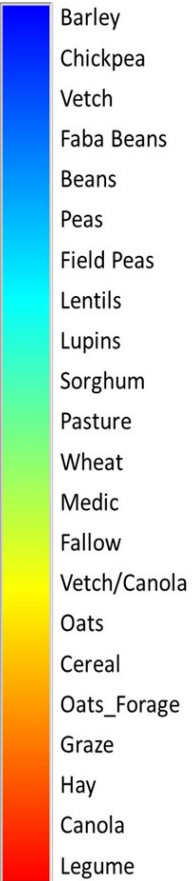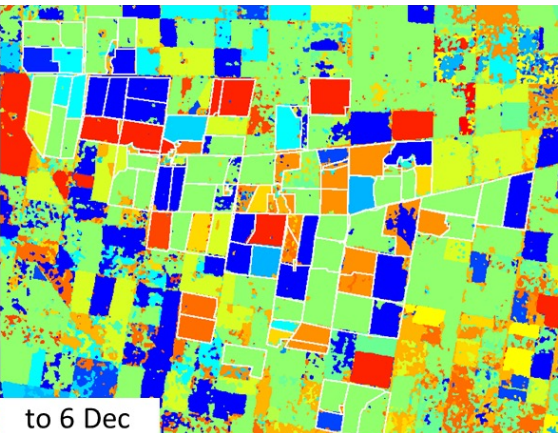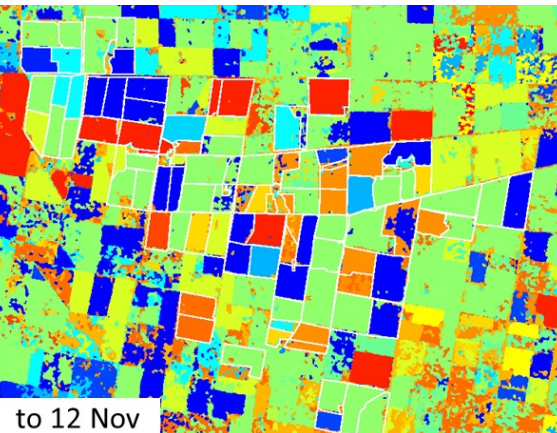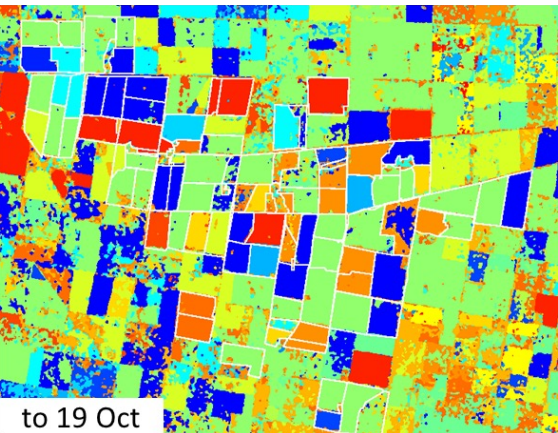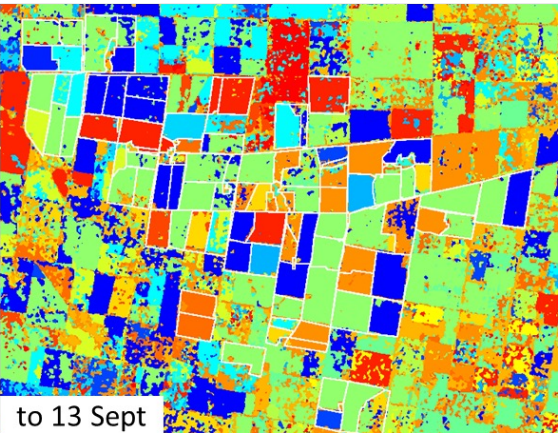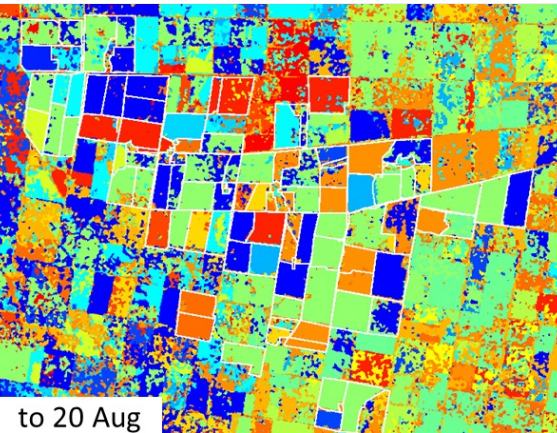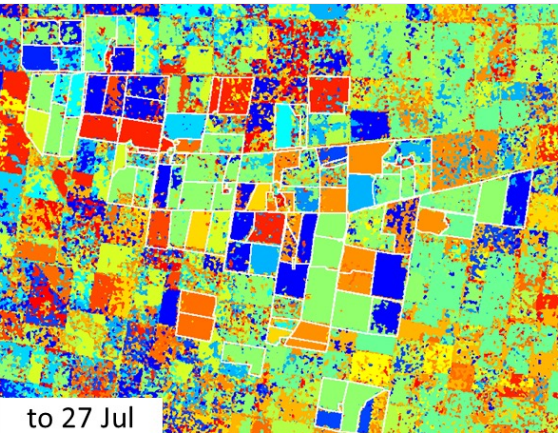
Crop Discrimination
## All Crops (left) vs Barely in blue + Wheat in green (right)
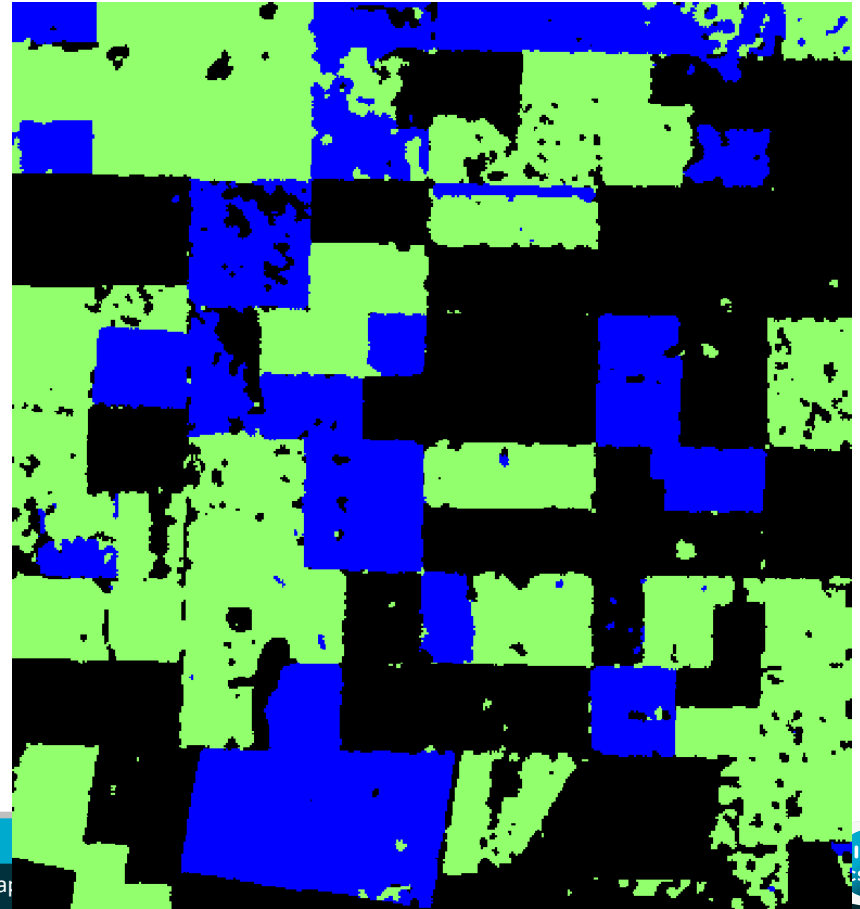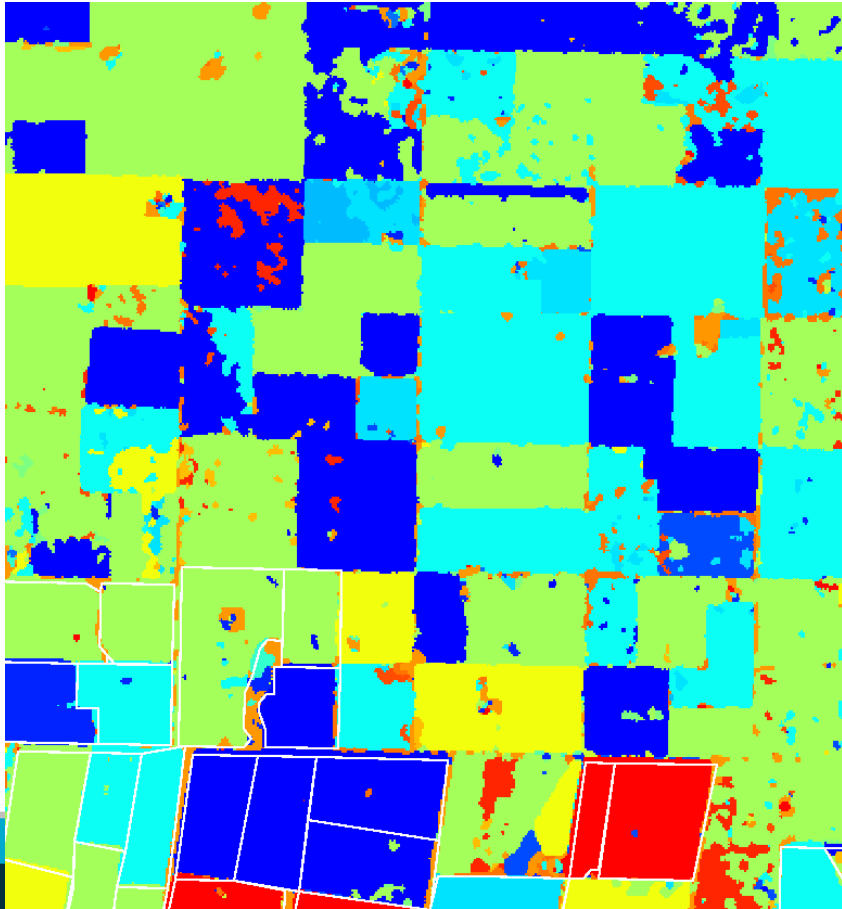
Predication Accuracy of Crop Classification based on CVA

| S1 Time Series	Acquisition Time Window	Separation Score	Percentage of Discrimination
5 Dates	10 April – 27 July	9.992	44.5
6 Dates	10 April – 8 Aug	11.252	50.1
7 dates	10 April – 20 Aug	12.520	55.7
8 Dates	10 April – 1 Sept	13.538	60.2
9 dates	10 April – 13 Sept	14.828	66.0
10 Dates	10 April – 25 Sept	16.228	72.2
11 Dates	10 April – 7 Oct	17.360	77.2
12 Dates	10 April – 19 Oct	18.243	81.2
13 Dates	10 April – 31 Oct	19.201	85.4
14 Dates	10 April – 12 Nov	21.048	93.6
15 Dates	10 April – 6 Dec	22.475	100

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Main Ground Sampling Data Located in the Overlap Region of the Neighbouring Orbits Vic01_orb089 and Vic02_orb016 - The sampling data can be used as training data for crop type classification of both Vic01 and Vic02 orbits
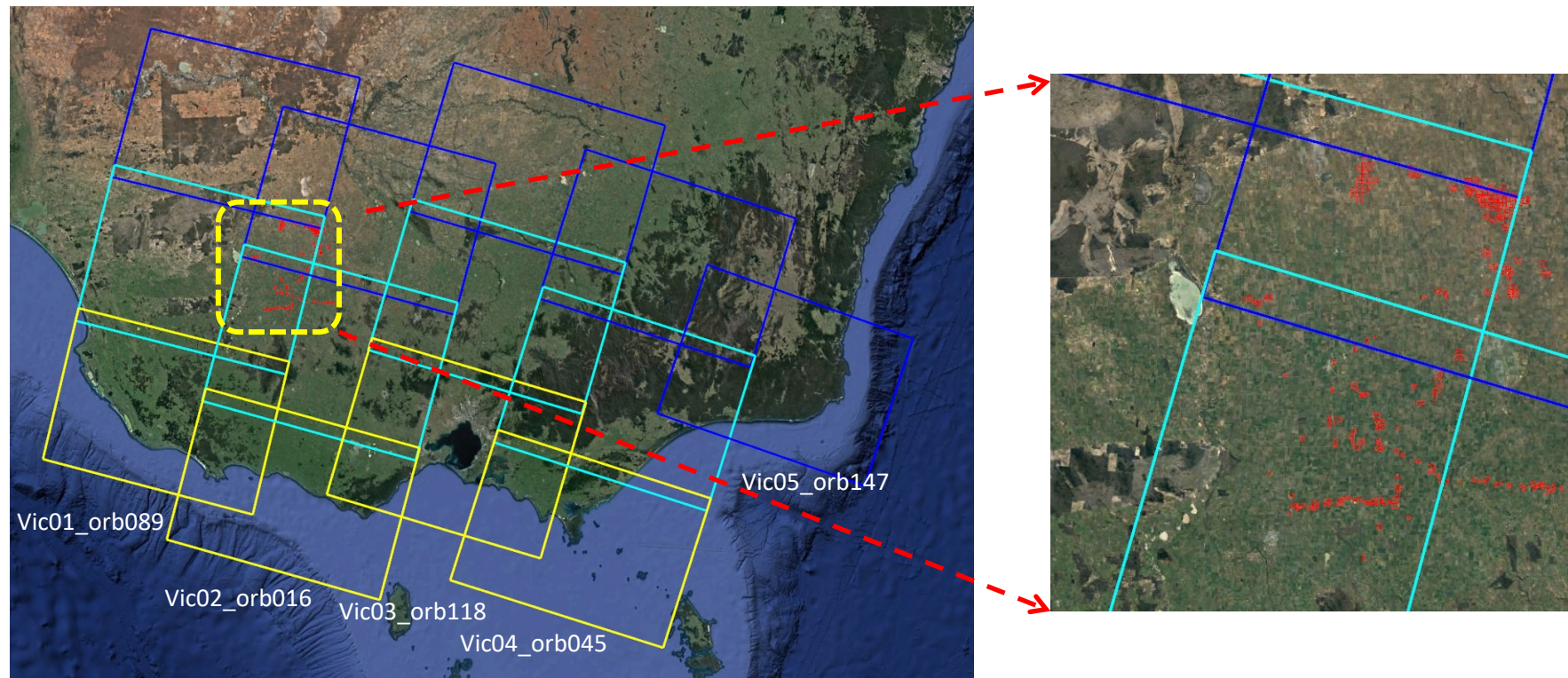
Crop Type Classification for Vic03, Vic04 and Vic05 Orbits via Training Dataset Propagation

- 5 Sentinel-1 consequent orbits for the whole state of Victoria,

- Ground sampling data were mainly collected within an intensive agriculture zone of the second orbit Vic02_orb016

- Approx. 78–85 km of overlapping area between images from neighbouring orbits in this region

- Random Forest classifier provides a probability map for each class apart from a classification map

- Create the training dataset in the overlapping area between Vic02 and Vic03 from the crop map of Vic02 based on the dominant probabilities (60%-90%) of classification layers derived by Random Forest for crop classification of Vic03

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Crop Type Classification for Vic03 Orbit with Training Dataset Propagation through Orbit Vic02
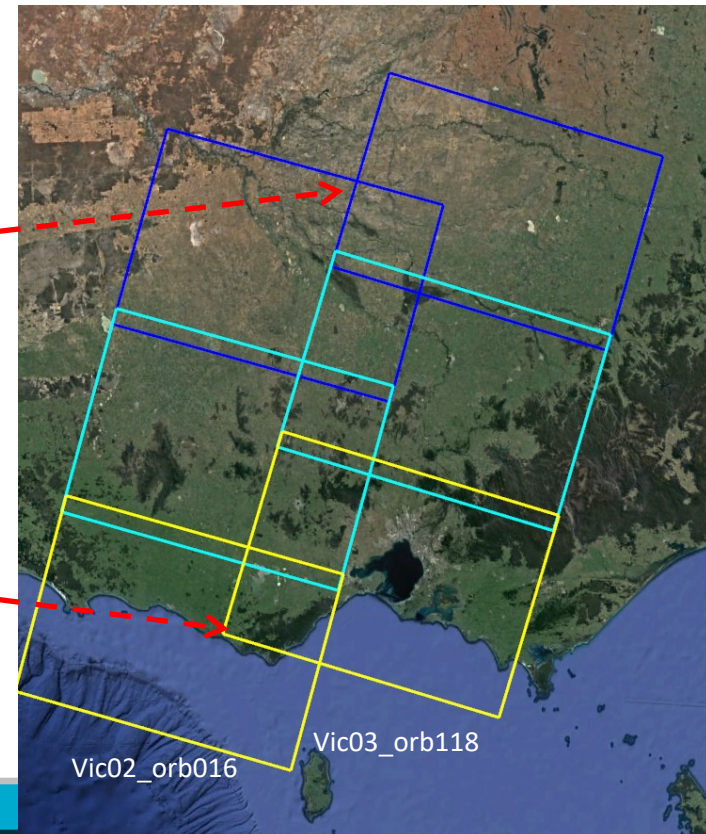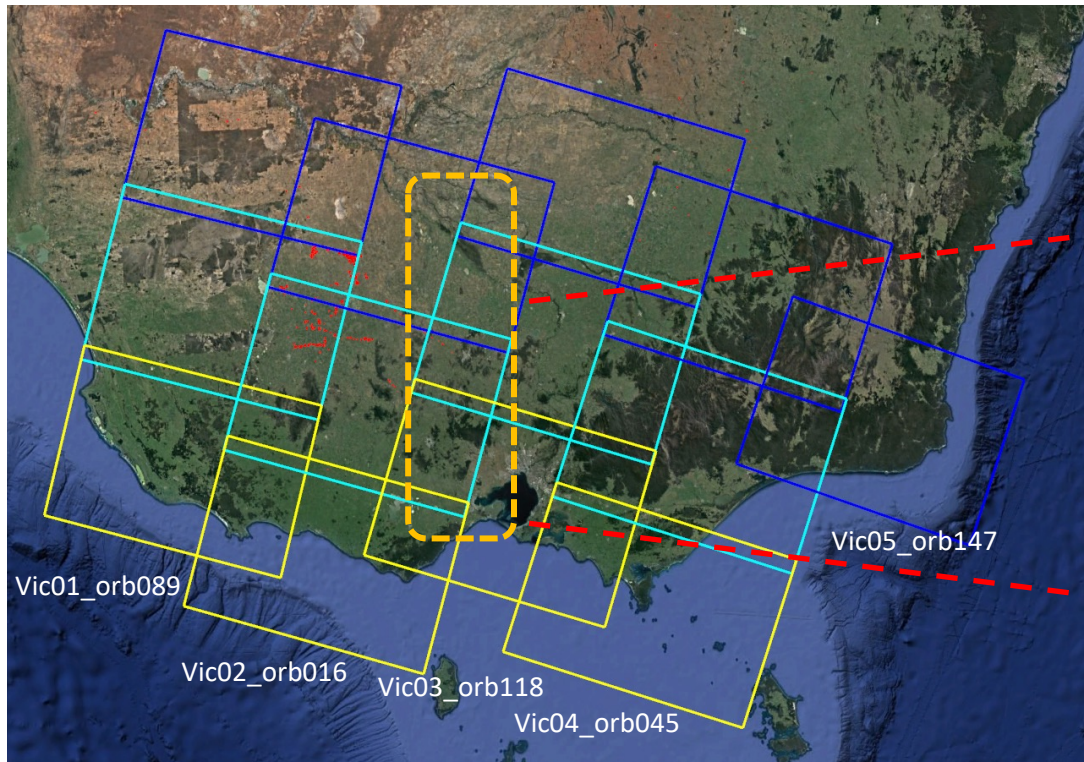
Crop Type Classification for Vic04 and Vic05 Orbits via Training Dataset Propagation

- Repeat the same process of classification propagation and crop classification for Vic04 and Vic05

- Mosaic the crop maps of all 5 orbits into a crop map for the whole state of Victoria

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State-wide Crop Map with Non-dryland Cropping Mask in Victoria Derived from 11 ~ 15 Dates of Sentinel-1 Time Series over the 2016 Growing Season
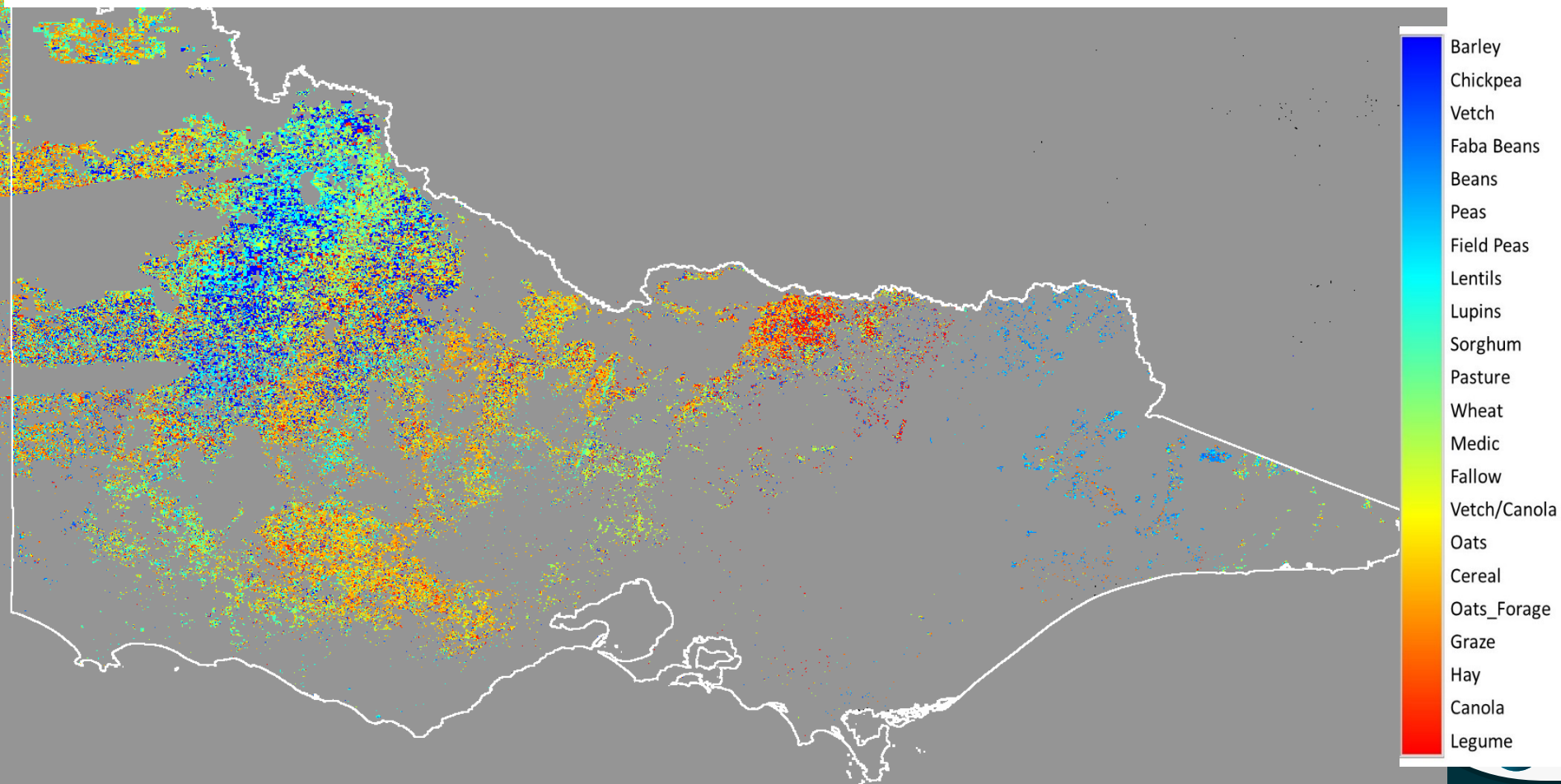
Summary

Agribusiness are keen to have crop map information with reasonable accuracy as early as possible

Trial investigation of large scale crop mapping started from the Wheatbelt in Victoria over the 2016 growing season and crop map with 25m pixel spacing was performed

Polarimetric analysis of dual-pol S1 data can provide additional information for better crop classification, area estimates and crop growing status monitoring.

Crop classifications with varying length of time series were compared. Longer time series shows better classification accuracy but early crop area predication with reasonable accuracy is feasible

Classification propagation is useful for large-scale crop mapping in case of lack of ground training data

National-scale crop mapping has been rolling out for all wheatbelts in Australia since 2017 until 2021.

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Footprints for 21 Relative Orbits of Sentinel-1A & 1B in Australia: Routine Acquisitions of Every 12 Days since Dec 2016
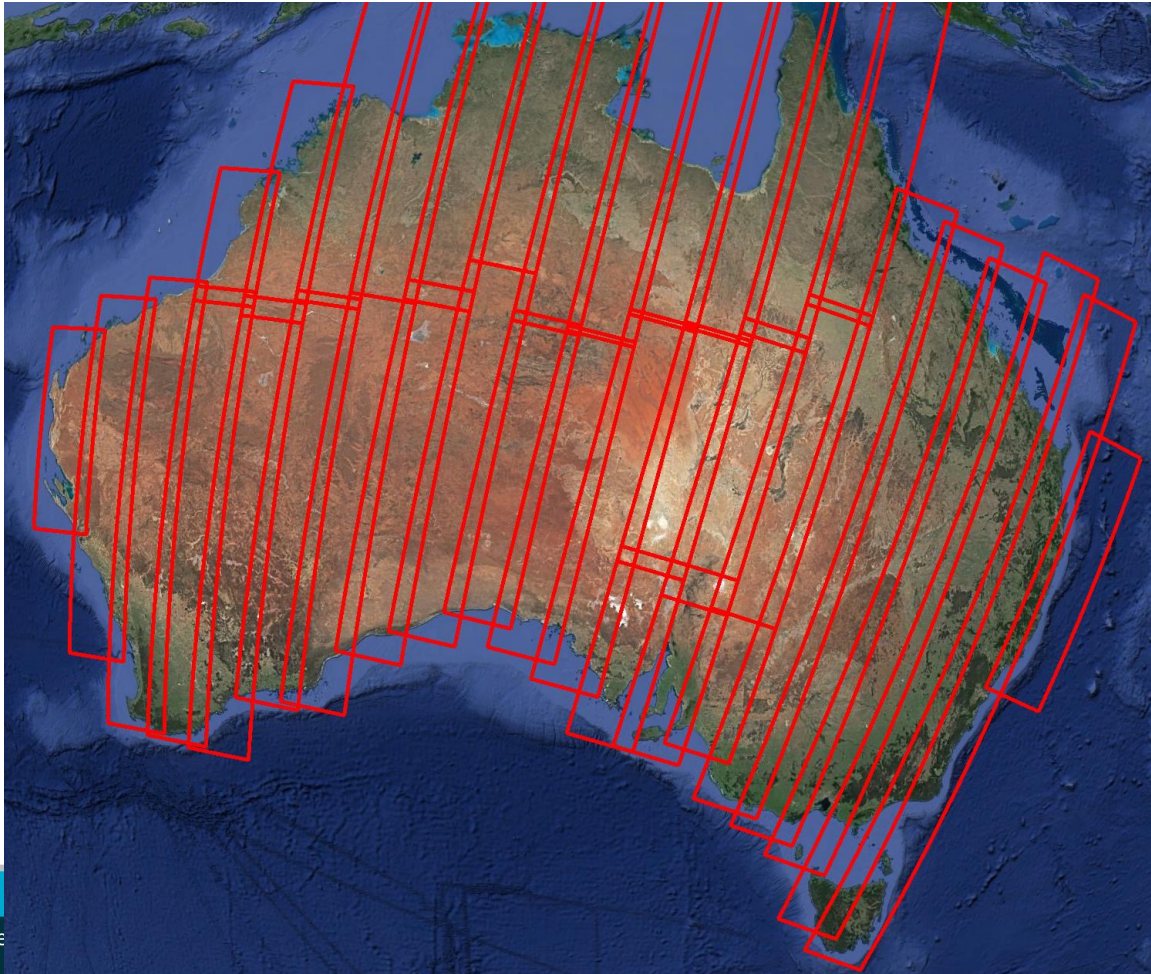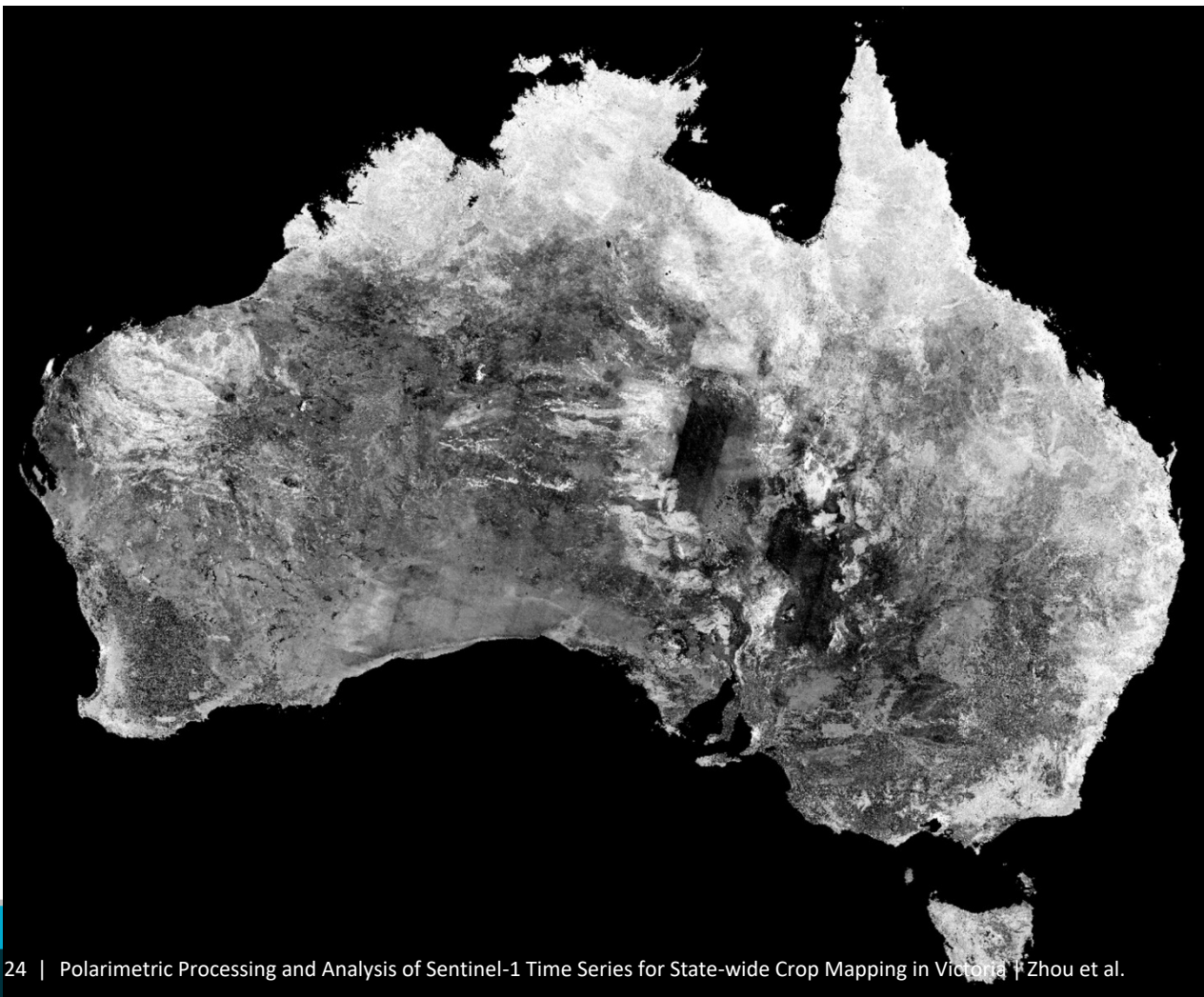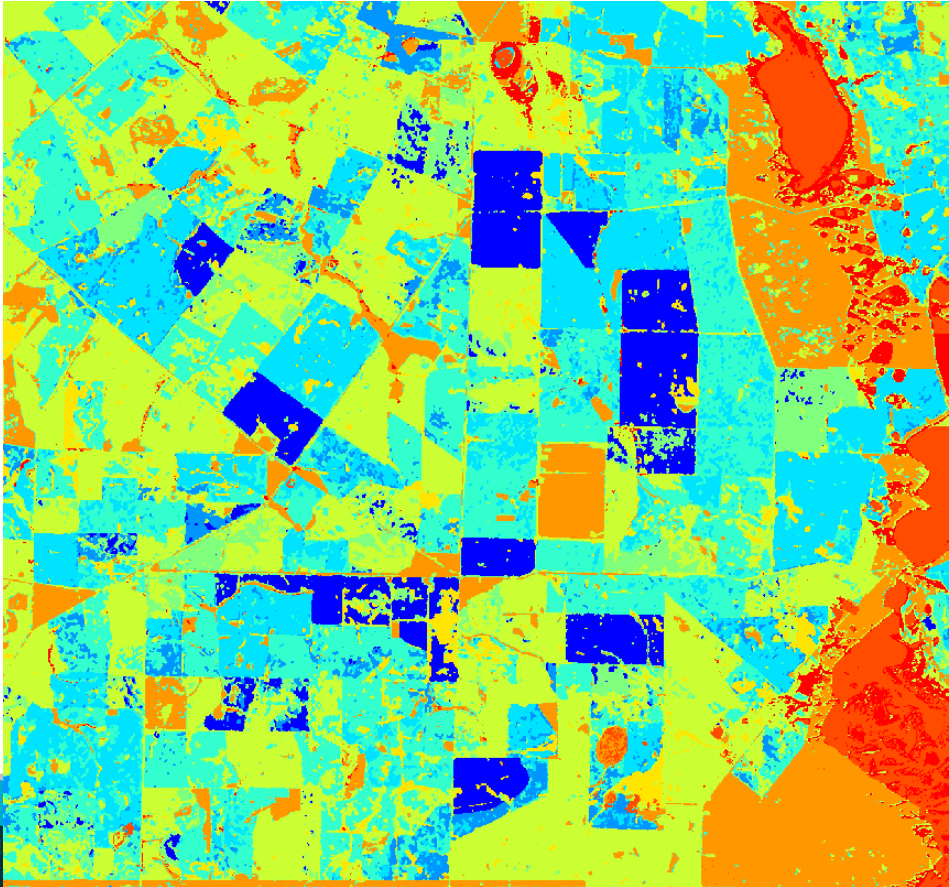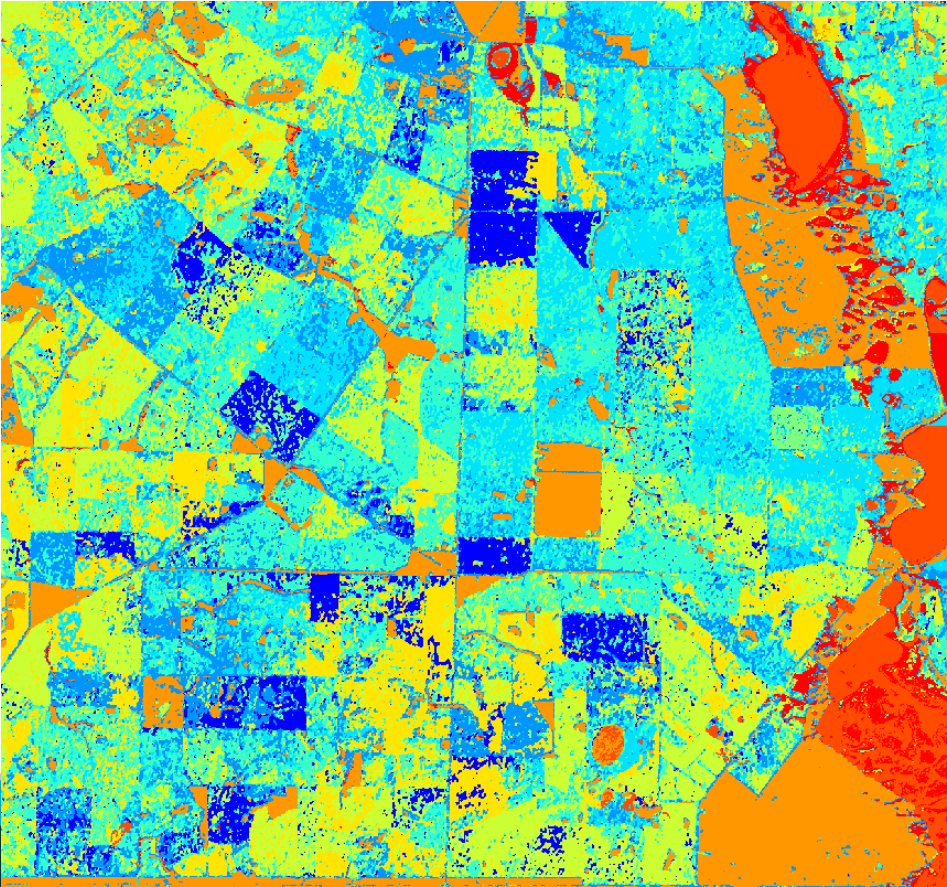
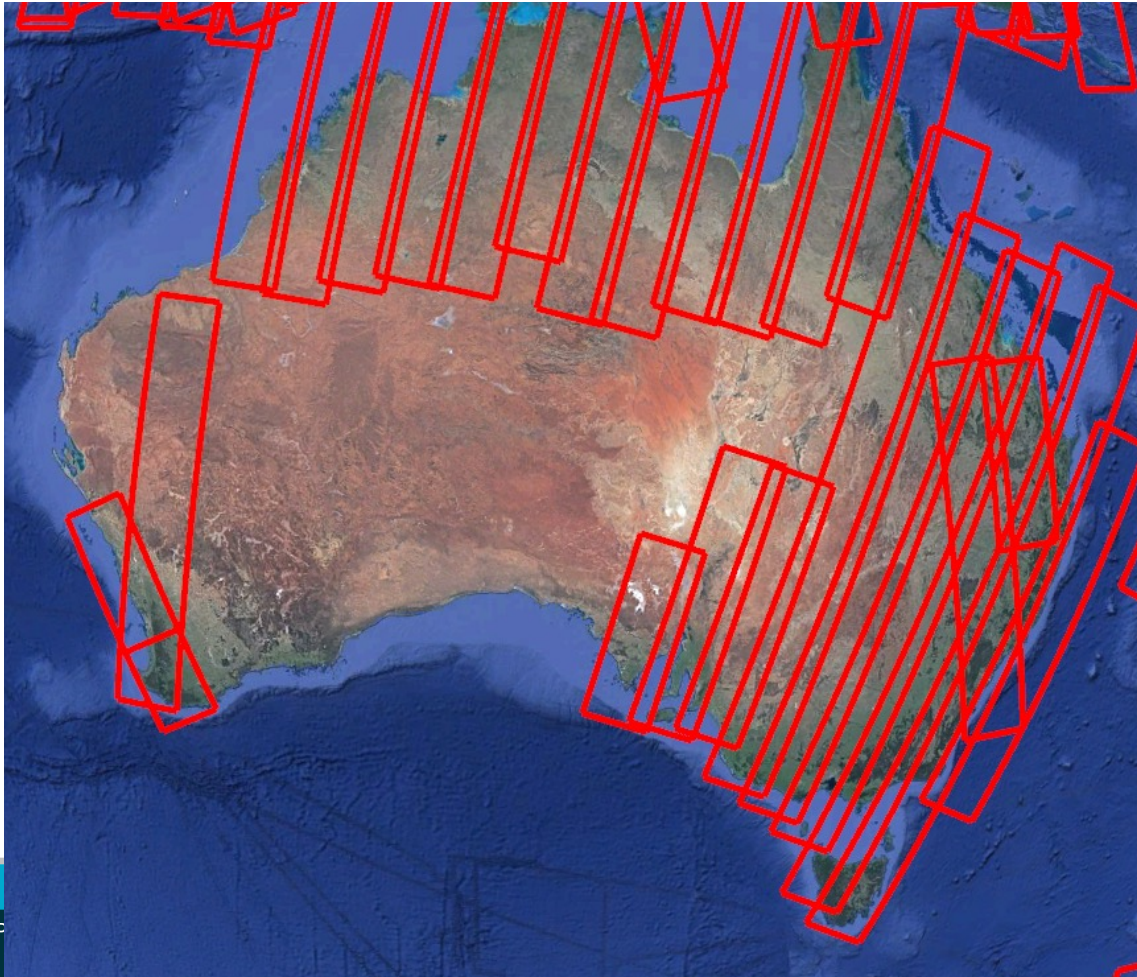**VV Mosaic** of 300 Sentinel-1 products acquired from 1 to 12 March 2018 within one full coverage cycle

No any gap !

Close-up: Crop Maps (31.5km x 29.5km) derived from 5 Dates (left: 3 June - 8 Aug 2018) and 8 Dates (right: 3 June - 11 Sept 2018)

Current Observations of Sentinel-1A in Australia after 23 December 2021

Main Impacts:
- No crop mapping in WA and SA from 2022
- Monthly state-wide land monitoring in WA shrunk to only 1/5 from 2022
- ...

Looking forward to Sentinel-1C launch!

Thank you

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