Integration and validation of phenology products at multiple-scales

Qiaoyun Xie, Alfredo Huete, Song Leng, Nguyen Ngoc Tran, Yuxia Liu

❖ University of Technology Sydney

Ecosystem Dynamics, Health and Resilience

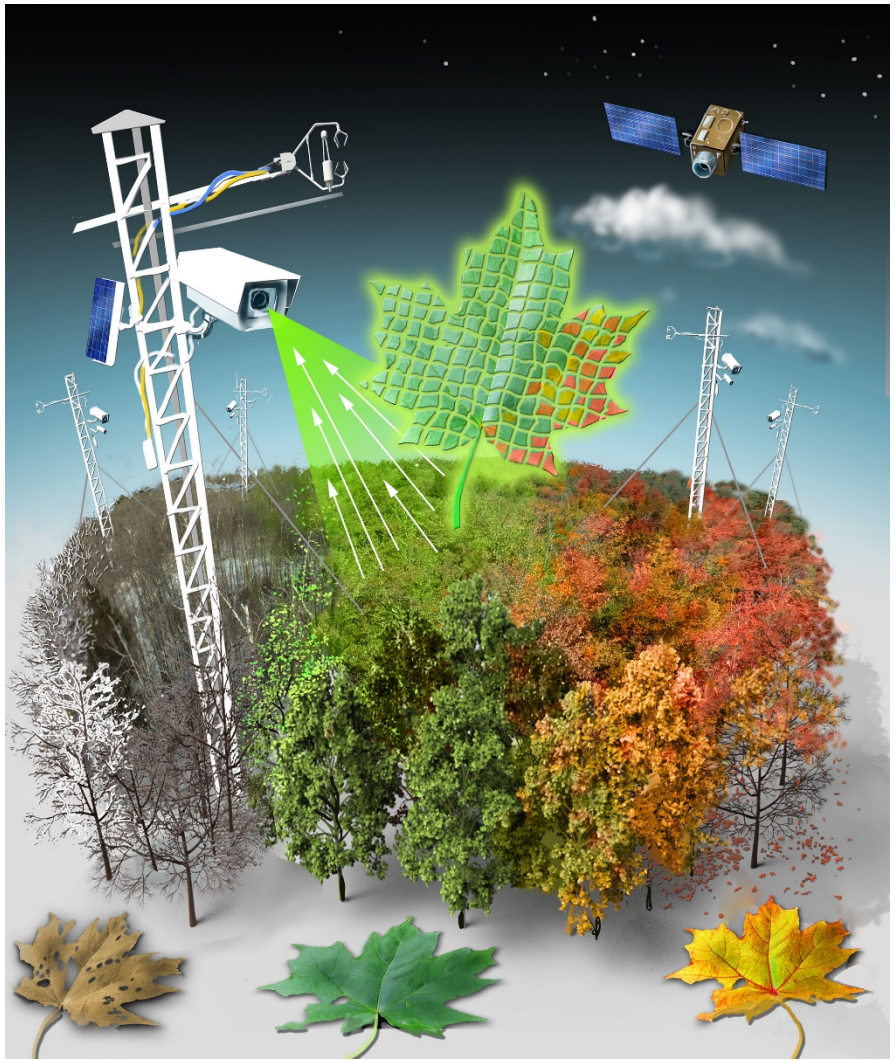
Faculty of Science

UTS
UNIVERSITY OF TECHNOLOGY SYDNEY

Outline

1. Phenology product at different scales for Australia
2. Validation of phenology product with phenocam
3. Drivers and controls of phenology
4. Conclusion

Background -- 1/3



- Phenology is the study of annually recurring biological life cycle events and the drivers and controls of their periodicity.
- Phenology is a characteristic property of ecosystem functioning and influences local to global biogeochemical and hydrological processes including photosynthesis, water cycling, and the energy balance.
- Shifts in phenology depict plants' integrated response to climate and environment, and thereby provide important landscape measures and indicators of change.

Background -- 2/3

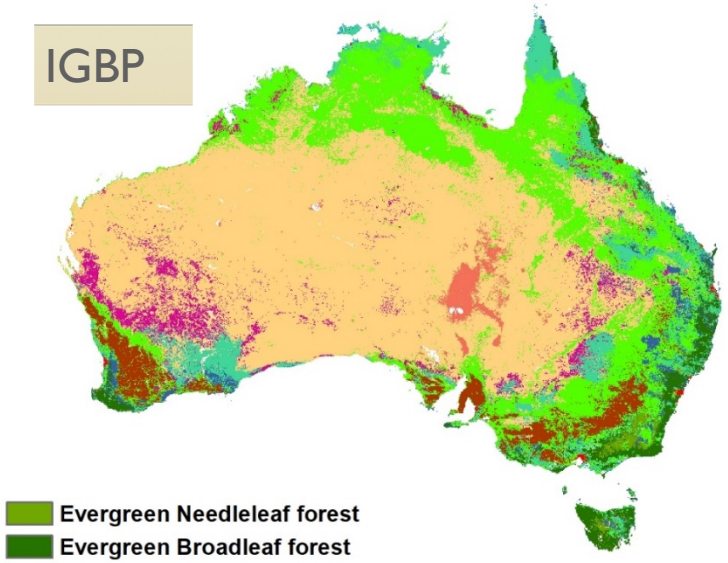
1. Current global phenology product (MCD12Q2) is NOT well-defined for Australia.
   - The algorithm works best for regions with well-defined growing seasons, such as the mid and high latitudes of the Northern Hemisphere.
   - The algorithm does not produce results if data is missing during transition periods or when the Enhanced Vegetation Index (EVI) amplitude is low.
2. A phenology product specifically designed for Australia's conditions is required. For example, algorithm should take into account:
   - Low EVI amplitude for forests at low latitude
   - Multi peaks for C4 grass at low latitude and C4 / C3 mixed grass area

Background -- 3/3

3. Finer land cover map for Australia

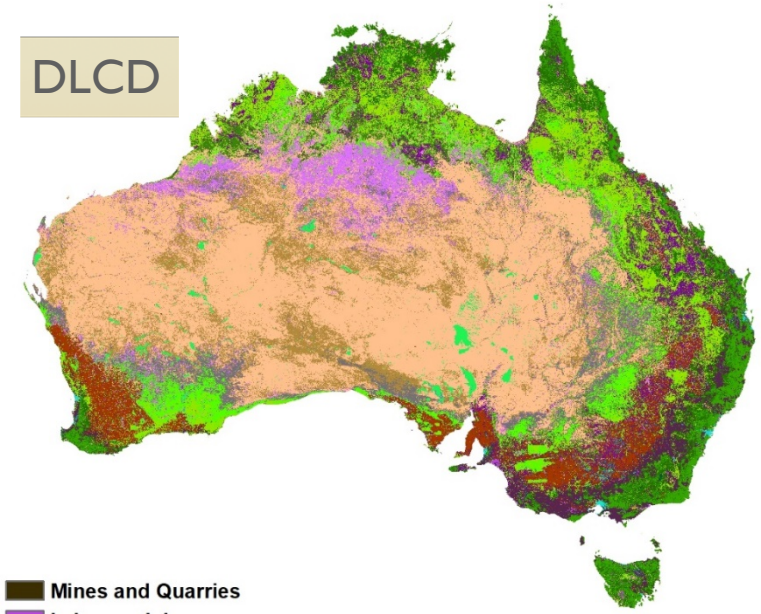
- The primary land cover scheme identifies **17 classes** defined by the International Geosphere Biosphere Programme (IGBP) at **500m** resolution.
- The Dynamic Land Cover Dataset (DLCD) shows Australian land covers clustered into **22 classes** at **250m** resolution.

IGBP



- Evergreen Needleleaf forest
- Evergreen Broadleaf forest
- Deciduous Needleleaf forest
- Deciduous Broadleaf forest
- Mixed forest
- Closed shrublands
- Open shrublands
- Woody savannas
- Savannas
- Grasslands
- Water
- Permanent wetlands
- Croplands
- Urban and built-up
- Cropland/Natural vegetation mosaic
- Snow and ice
- Barren or sparsely vegetated

DLCD



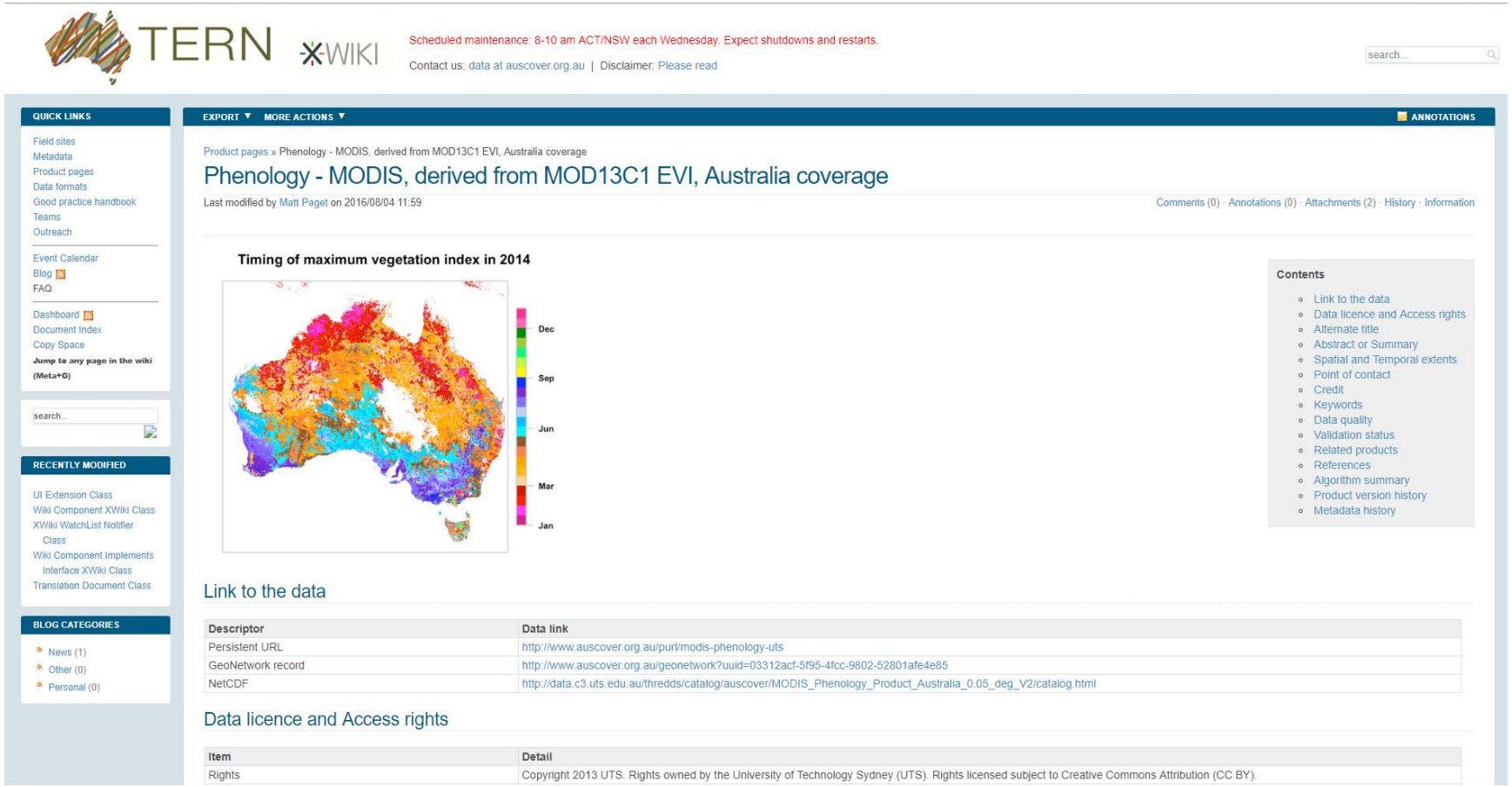
- Mines and Quarries
- Lakes and dams
- Salt Lakes
- Irrigated Cropping
- Irrigated Pasture
- Irrigated Sugar
- Rain fed Cropping
- Rain fed Pasture
- Rain fed Sugar
- Wetlands
- Closed Tussock Grassland
- Alpine meadows
- Open Hummock Grassland
- Open Tussock Grassland
- Scattered shrubs and grasses
- Dense Shrubland
- Open Shrubland
- Closed Forest
- Open Forest
- Open Woodland
- Woodland
- Urban Areas

Phenology product at different scales for Australia

Australian Phenology Product -- 1/2

- Australian Phenology Product ***Version 1***: A continental phenology product at 0.05 deg resolution from 2000 to 2015.

Terrestrial Ecosystem Research Network (TERN) project delivery.
http://data.auscover.org.au/xwiki/bin/view/Product+pages/Phenology+MOD13C2+UTS



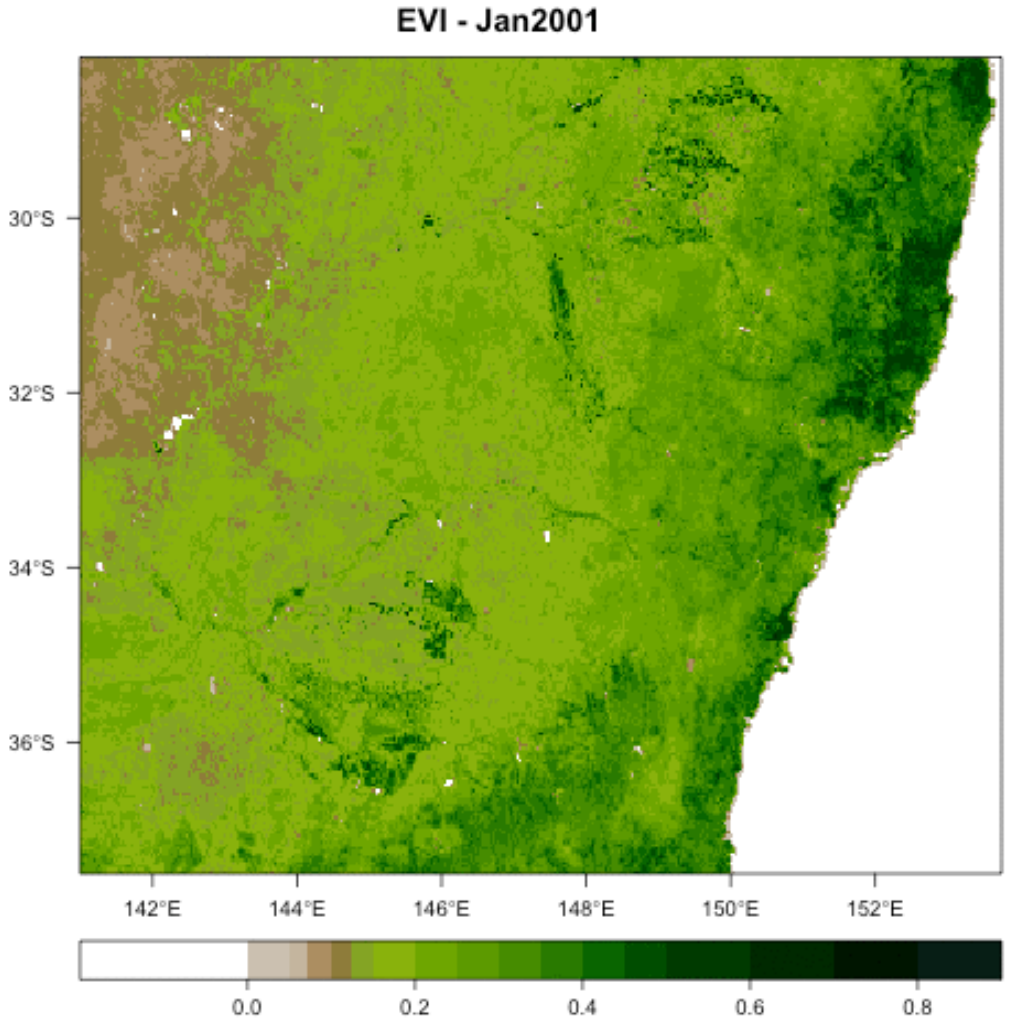
Australian Phenology Product -- 2/2

❖ Australian Phenology Product ***Version 2***: A continental phenology product at 250 m, derived from MODIS sensor continuity from 2000-present.

Terrestrial Ecosystem Research Network (TERN) project (to be delivered in 2019).

- Per-pixel metrics include Start of the growing season (SGS), Peak time of GS (PGS), End of GS (EGS), Length of GS (LGS), peak value, amplitude, min value, integrals, rate of greening, rate of curing and number of growing seasons.
- Validate phenology timing metrics through use of (i) Flux tower measures of seasonal gross primary productivity (GPP) and light use efficient (LUE); and (ii) Phenocam networks.
- Trial experimental sub-continental phenology metrics over select areas derived from Sentinel-2 sensor at 10 m spatial resolution, and Himawari-8 at 1 day temporal precision.

Enhanced Vegetation Index (EVI) and phenology -- 1/2



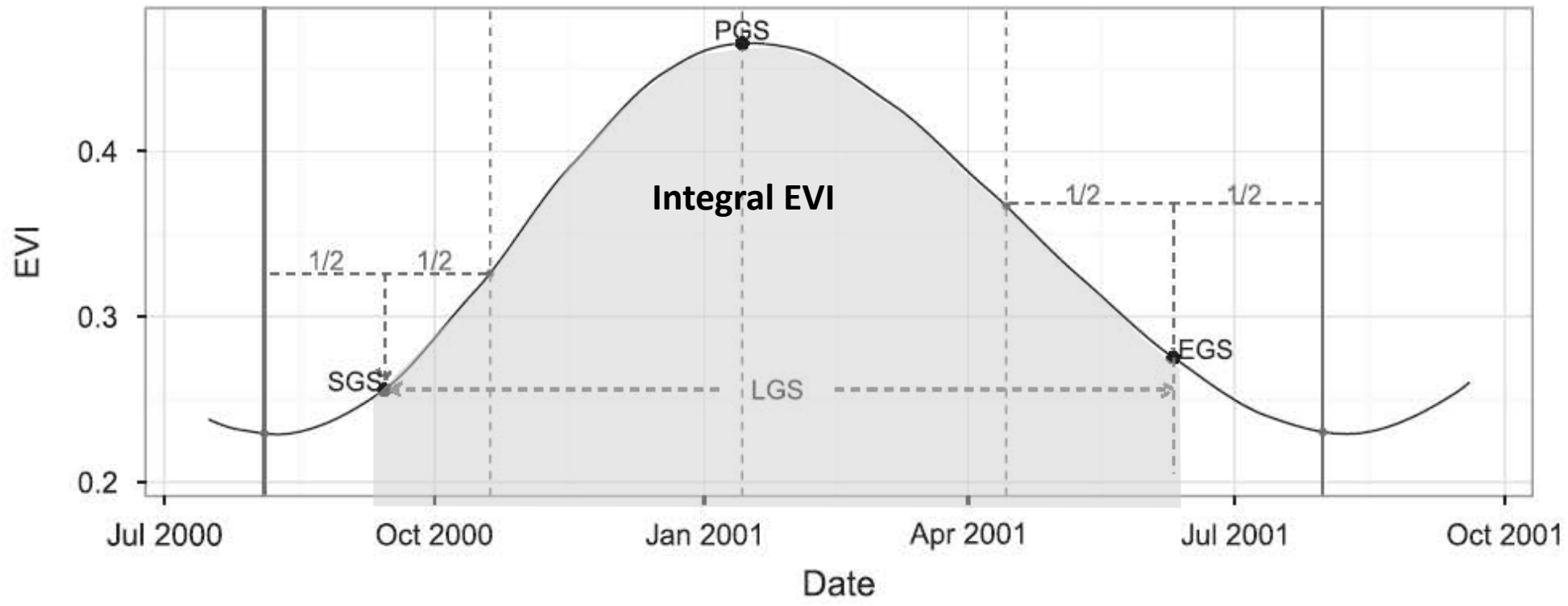
MODIS EVI Time Series (greenness)

$$EVI = G \times \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + C_1 \times \rho_{red} - C_2 \times \rho_{blue} + L}$$

Enhanced Vegetation Index (EVI):

- A proxy of canopy "greenness", which is defined as an integrative composite property of green leaf area, green foliage cover and structure, and leaf chlorophyll content.
- A function of remotely sensed reflectance (ρ) in the near infrared (nir), red, and blue bands.

Enhanced Vegetation Index (EVI) and phenology -- 2/2

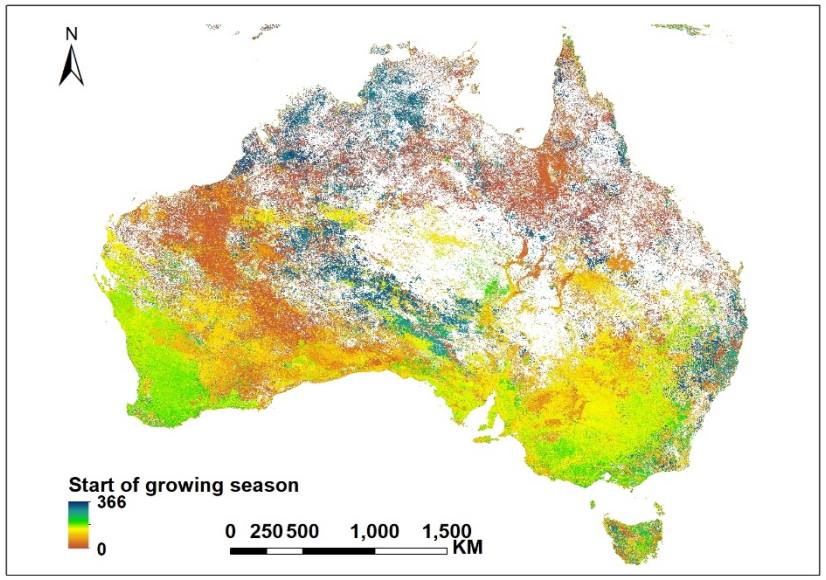


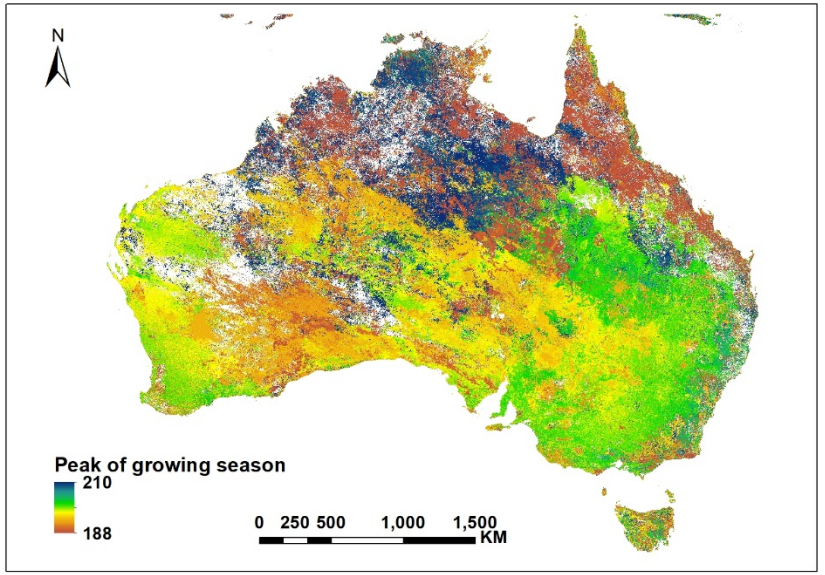
Enhanced Vegetation Index (EVI): Can, for example, define:

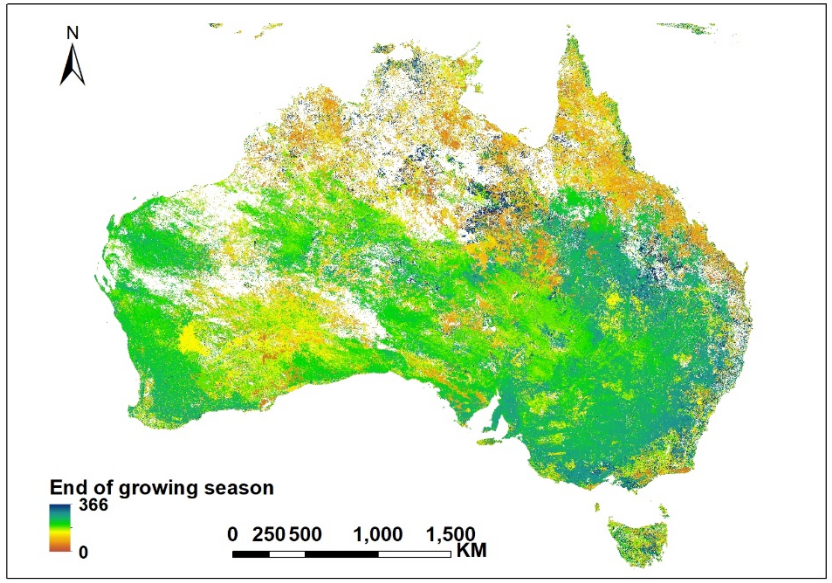
- Start of Growing Season (SGS)
- Peak of Growing Season (PGS)
- End of Growing Season (EGS)
- Length of Growing Season (LGS)

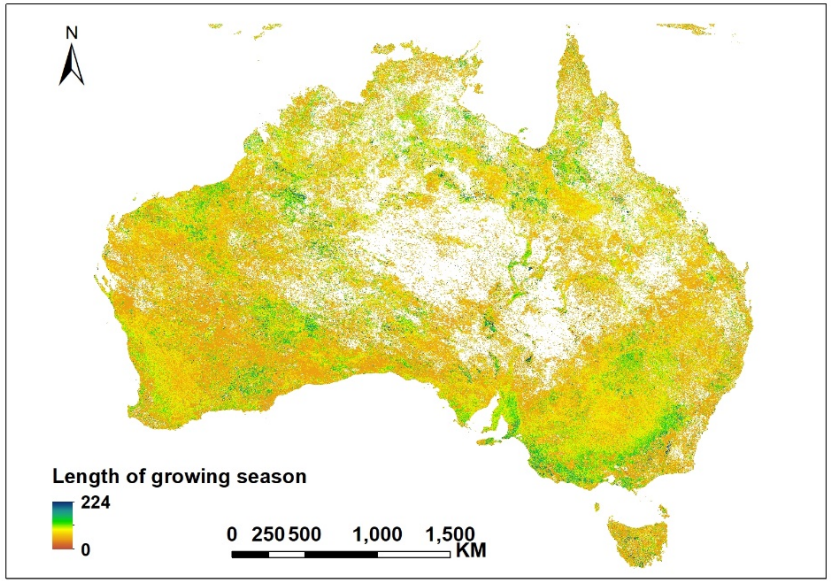
Figure credit: Ma et al. 2013 Remote Sensing of Environment

Australian phenology product *V2* -- 2016-2017 SGS, PGS, EGS, LGS (250m)



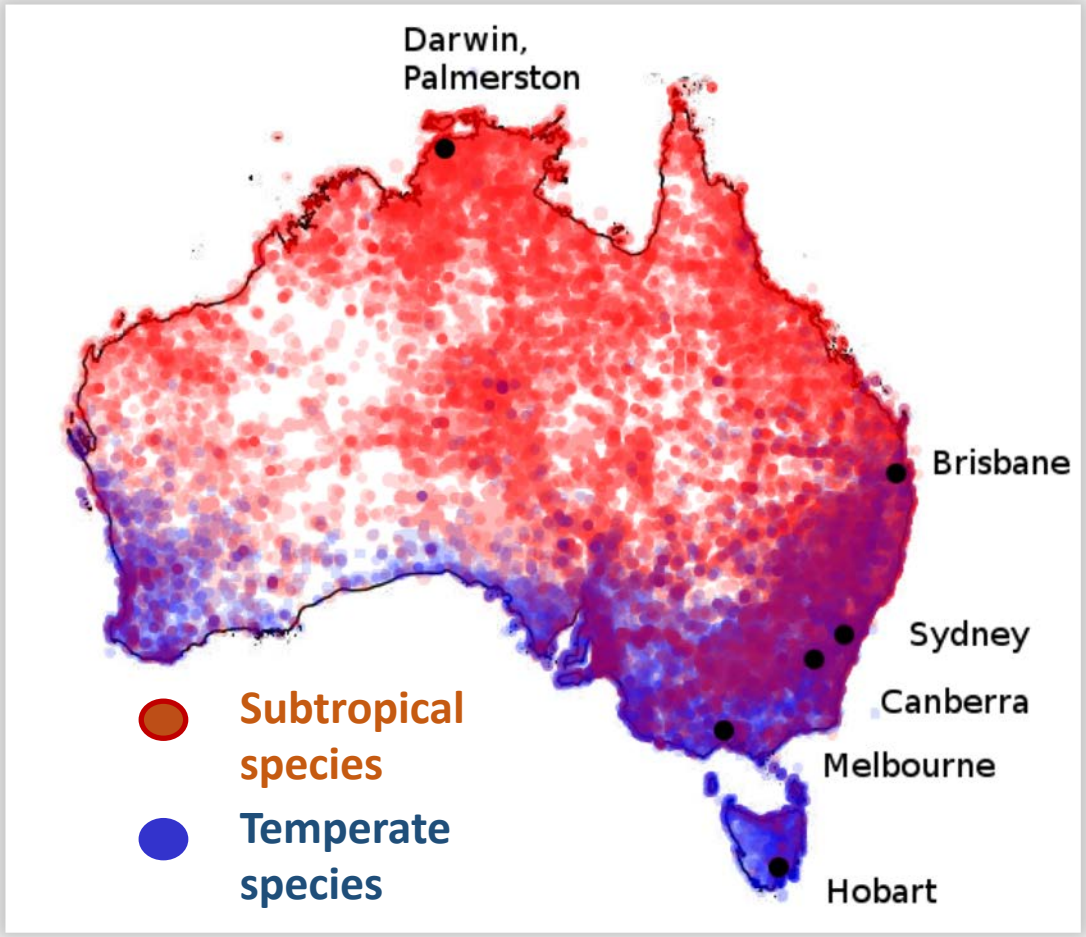






A case study of Australian grasslands
-- grass functional type distribution discriminated with phenology product

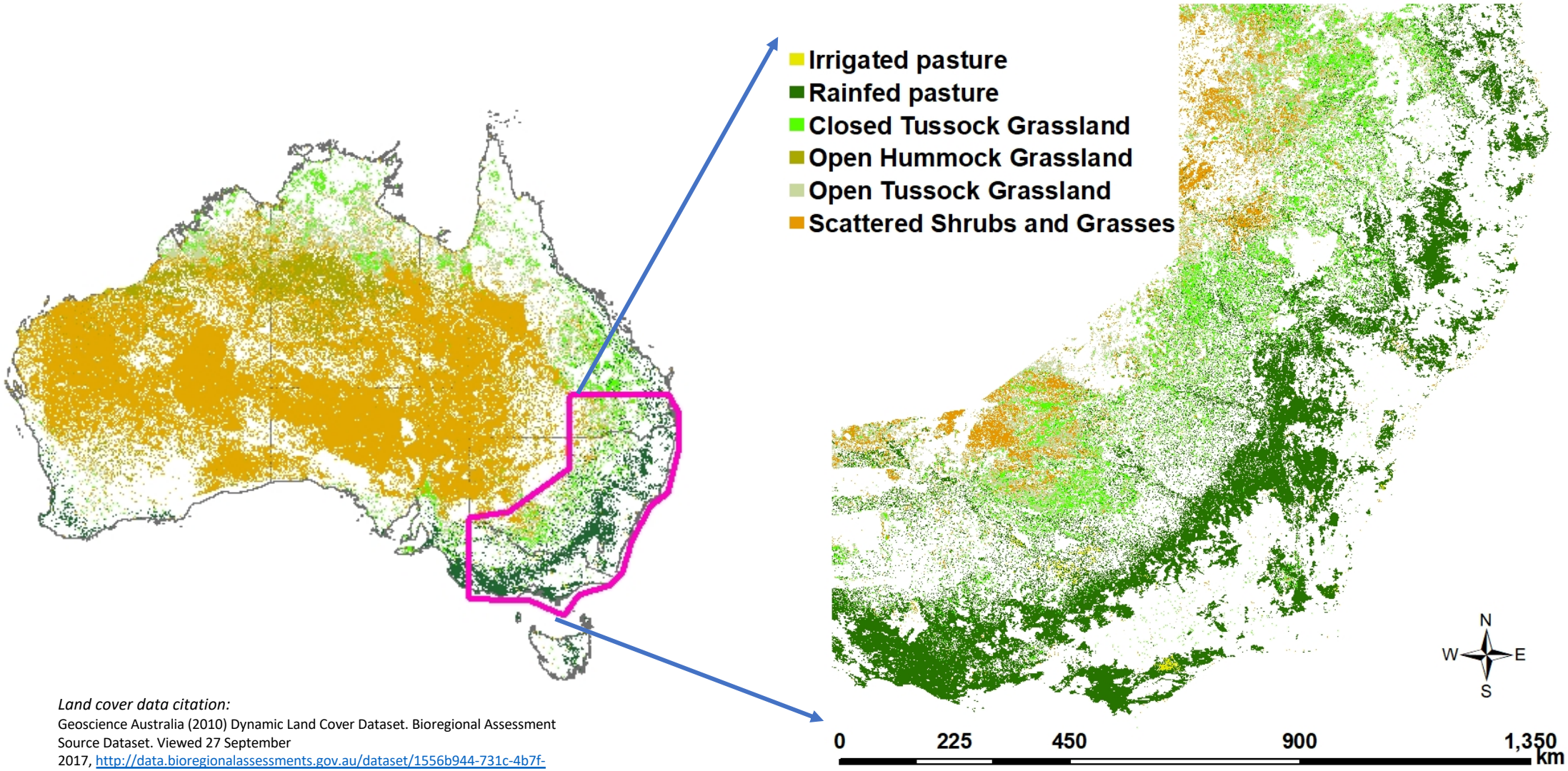
❖ Distribution of subtropical and temperate grass species



Medek et al. Aerobiologia 2016

- The grass and pasture lands in Australia are essential contributors to the agricultural production of wool, lamb, and beef.
- The highly productive eastern Australian belt is complex due to a mix of temperate (C3) and subtropical (C4) grasses.
- Phenology informs grass functional types. Remote sensing provides an approach for monitoring these grass / pasture over a large area.

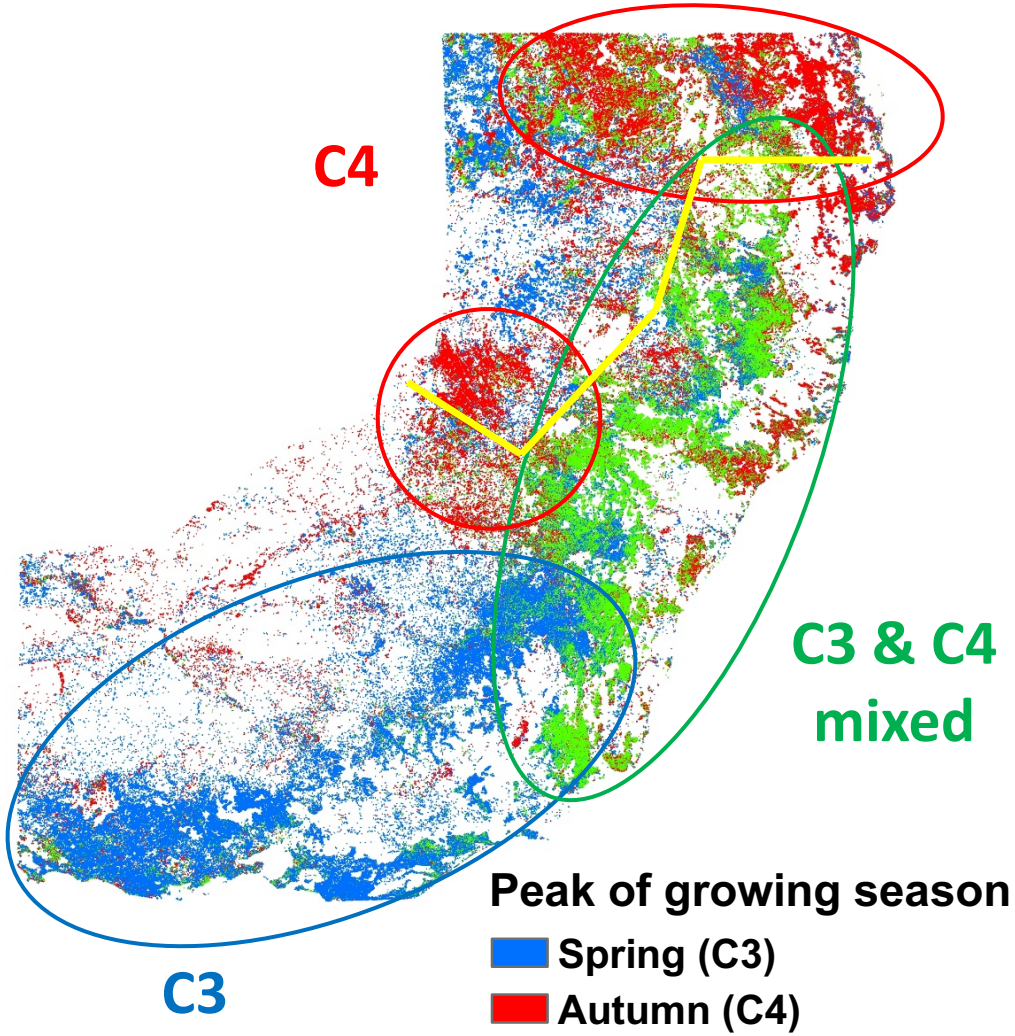
Study area -- eastern Australia grass / pasture



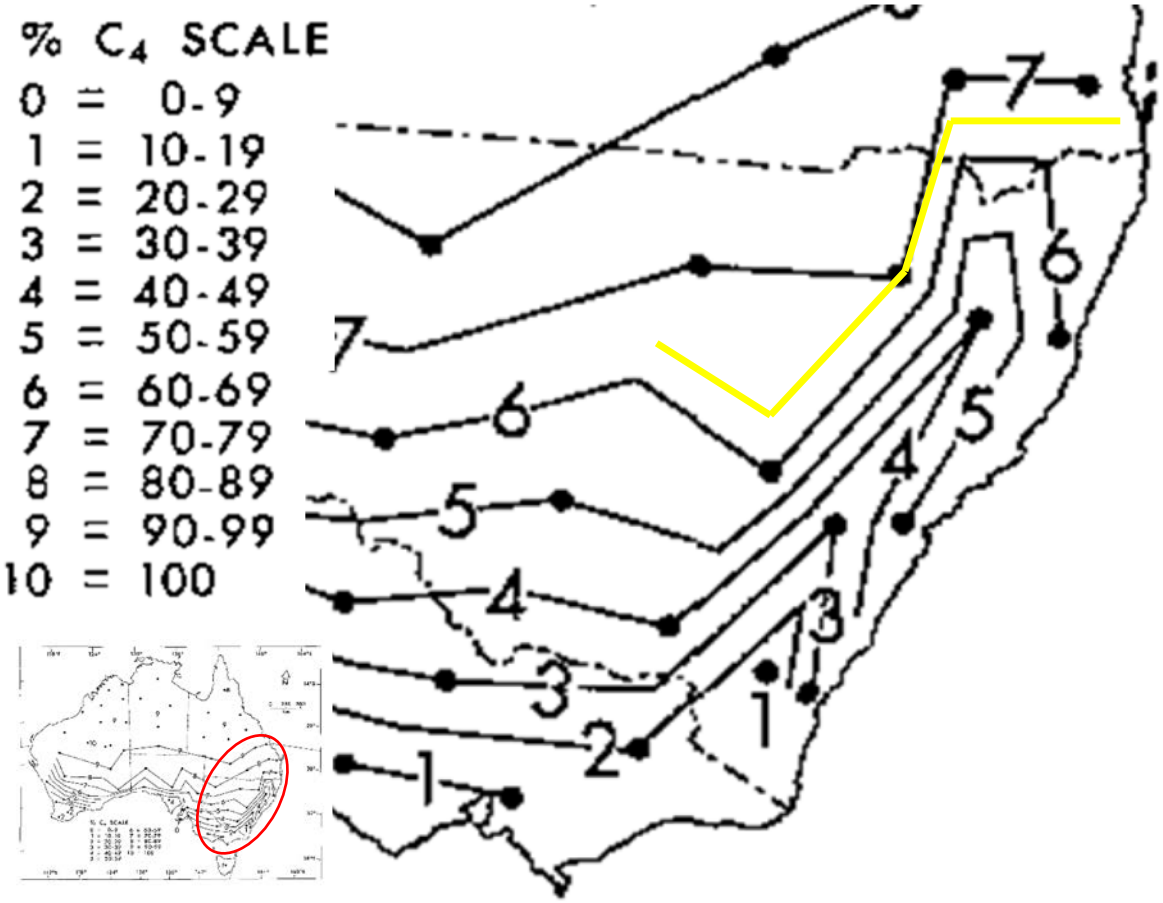
Land cover data citation:
Geoscience Australia (2010) Dynamic Land Cover Dataset. Bioregional Assessment Source Dataset. Viewed 27 September 2017, http://data.bioregionalassessments.gov.au/dataset/1556b944-731c-4b7f-a03e-14577c7e68db.

Grass distribution map (250m) 1/5 -- from remote sensing phenology

❖ **Grass distribution map (250m)**
-- from remote sensing phenology



❖ Subdivisional % C4 (native) map for Australia
-- using meteorology method

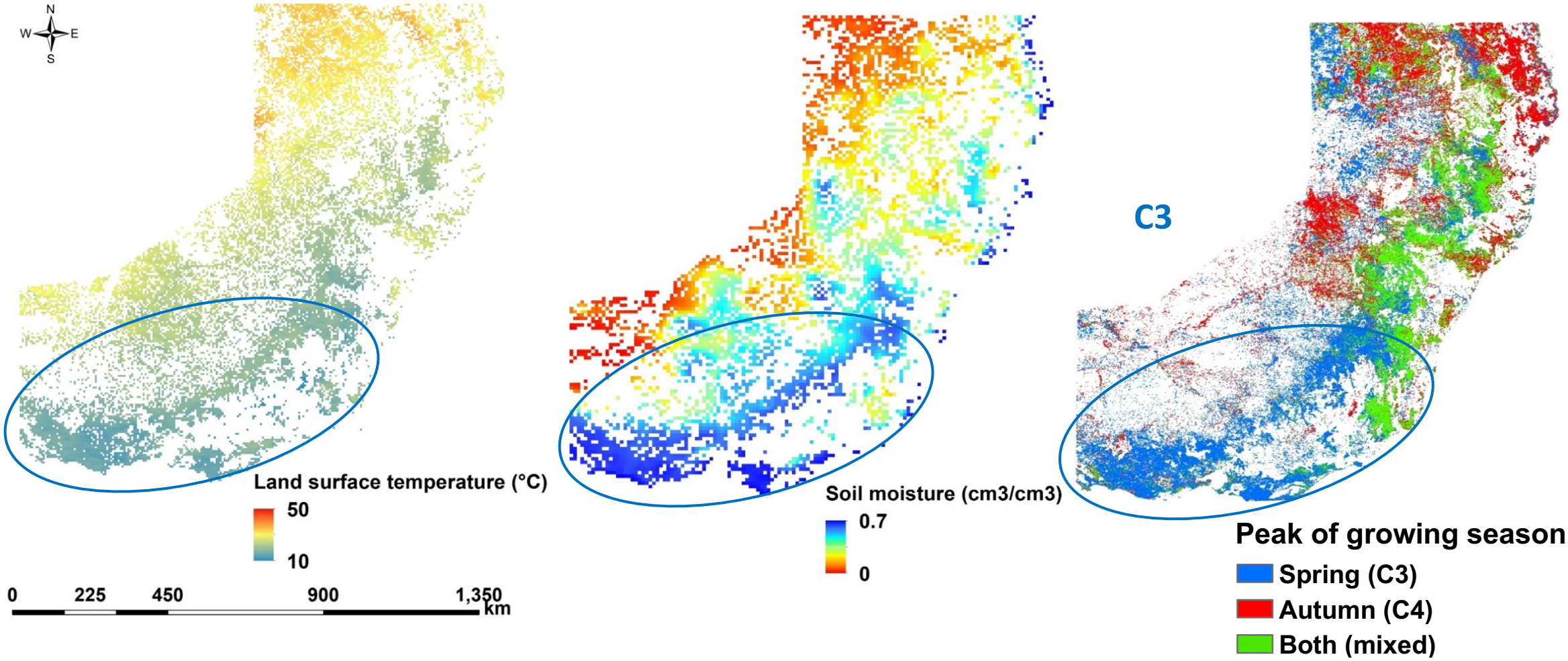


P.W.Hattersley et al. 1983 Oecologia

Grass distribution map (250m) 2/5 -- validated with climate factor

Land surface temperature and soil moisture in **October 2016 (spring)**

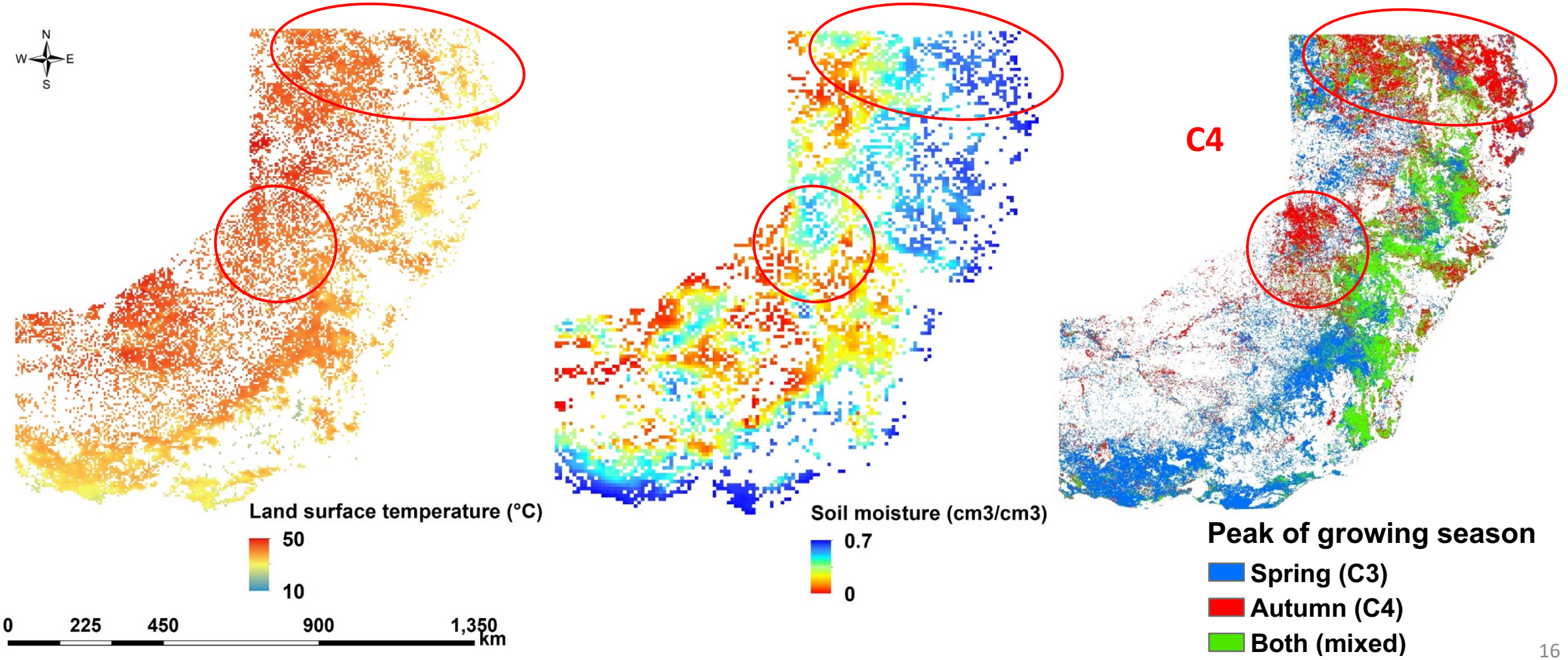
- C3 grass is most numerous where spring is cool and wet *(P.W.Hattersley et al. 1983 Oecologia)*



Grass distribution map (250m) 3/5 -- validated with climate factor

Land surface temperature and soil moisture in **January 2017 (summer)**

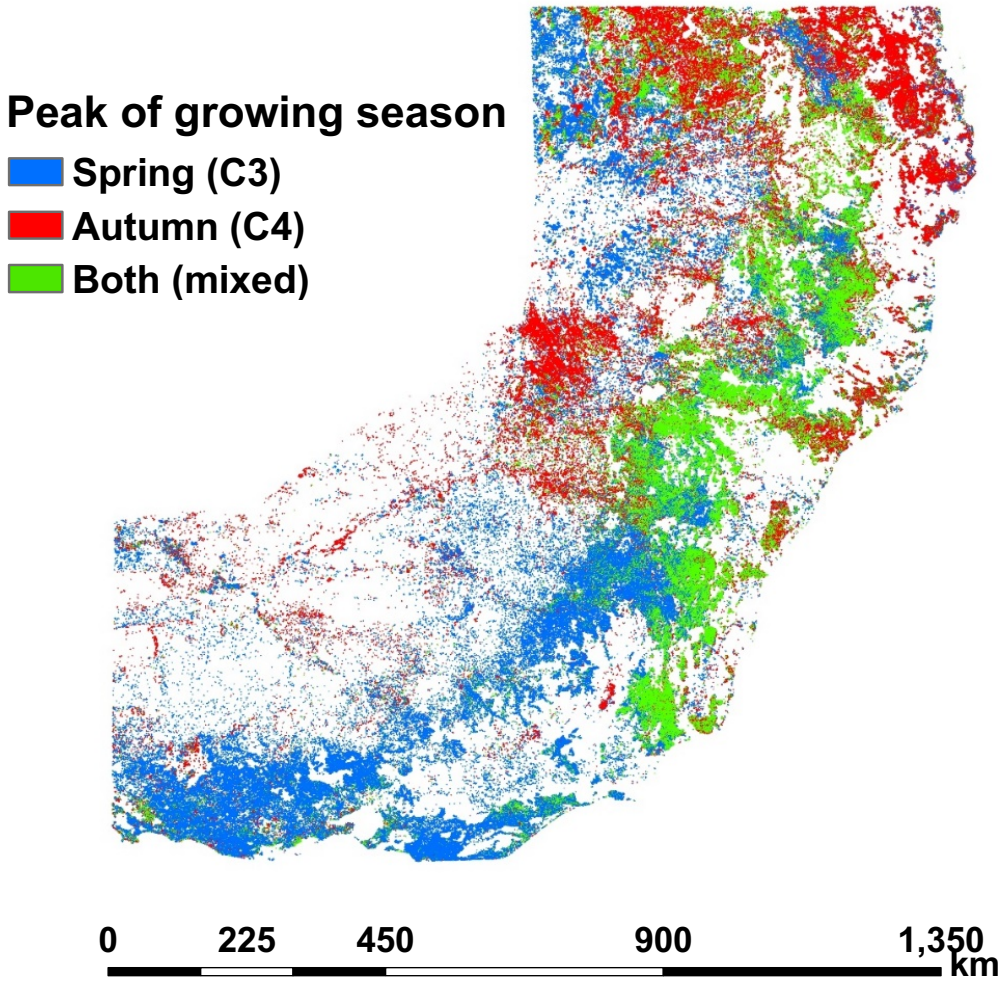
- C4 grass is most numerous where summer is hot and wet *(P.W.Hattersley et al. 1983 Oecologia)*



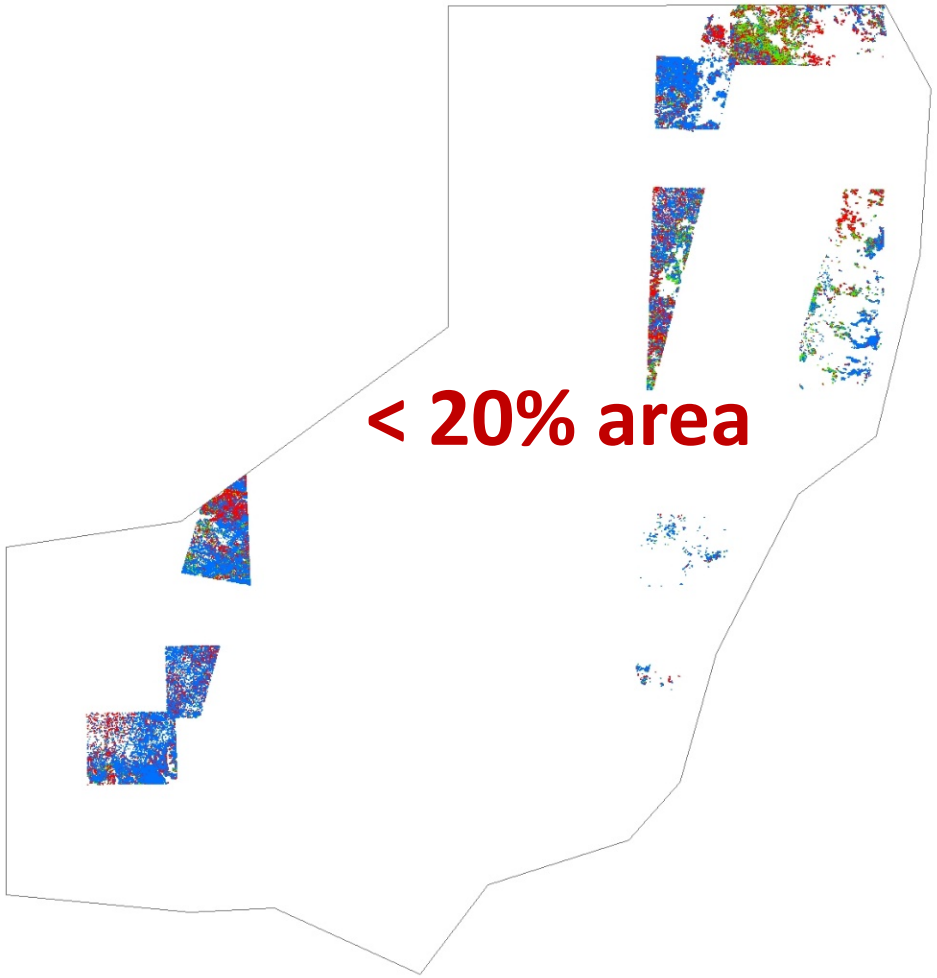
Grass distribution map (250m) 4/5

-- from MODIS (250m) to Sentinel-2 (10m)

❖ MODIS (250m)



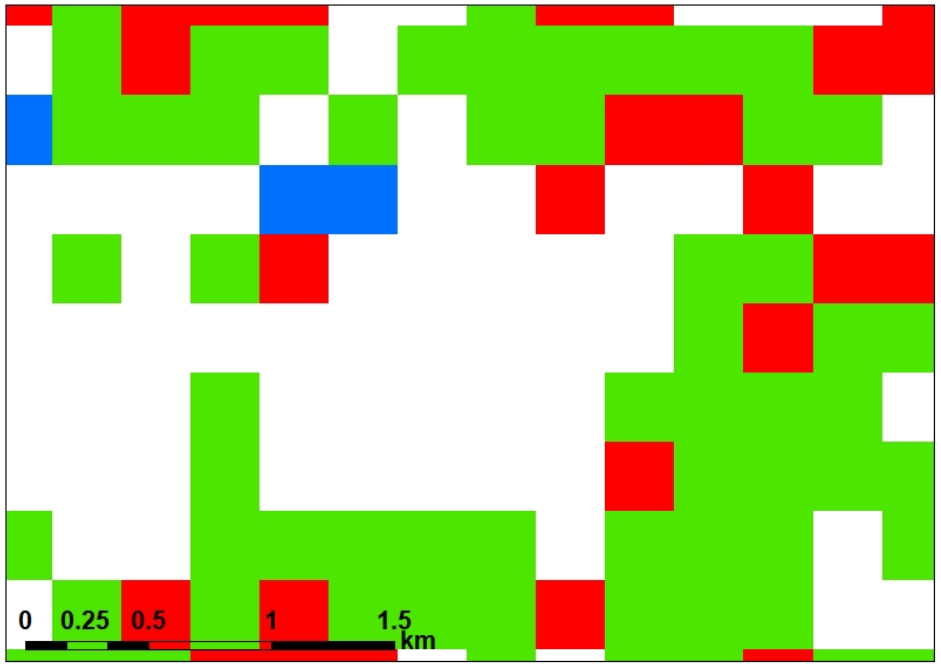
❖ Sentinel-2 (10m)



Grass distribution map (250m) 5/5

-- from MODIS (250m) to Sentinel-2 (10m)

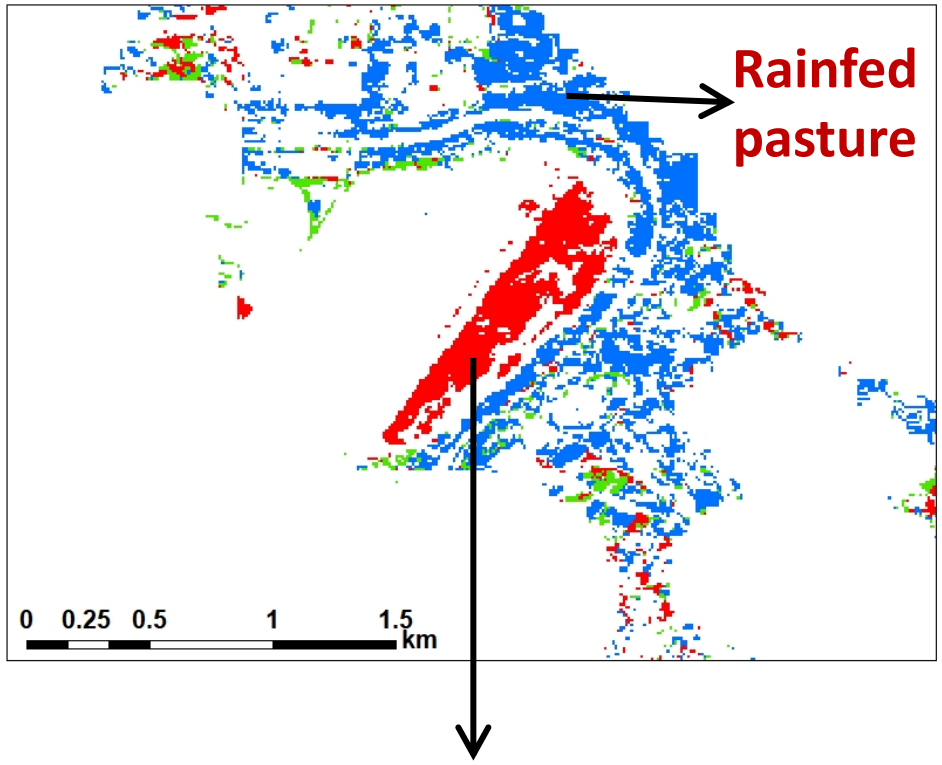
❖ MODIS (250m)



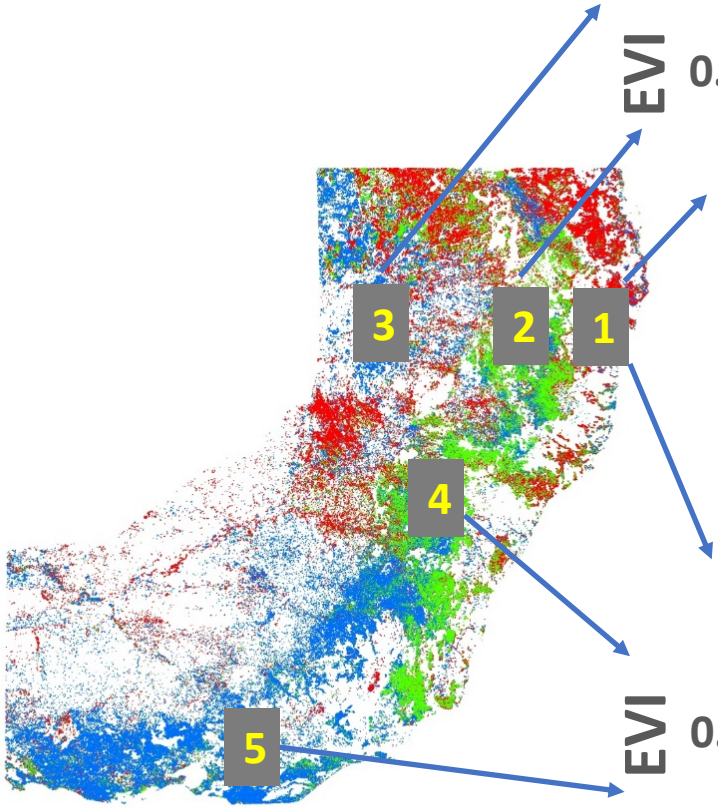
Peak of growing season

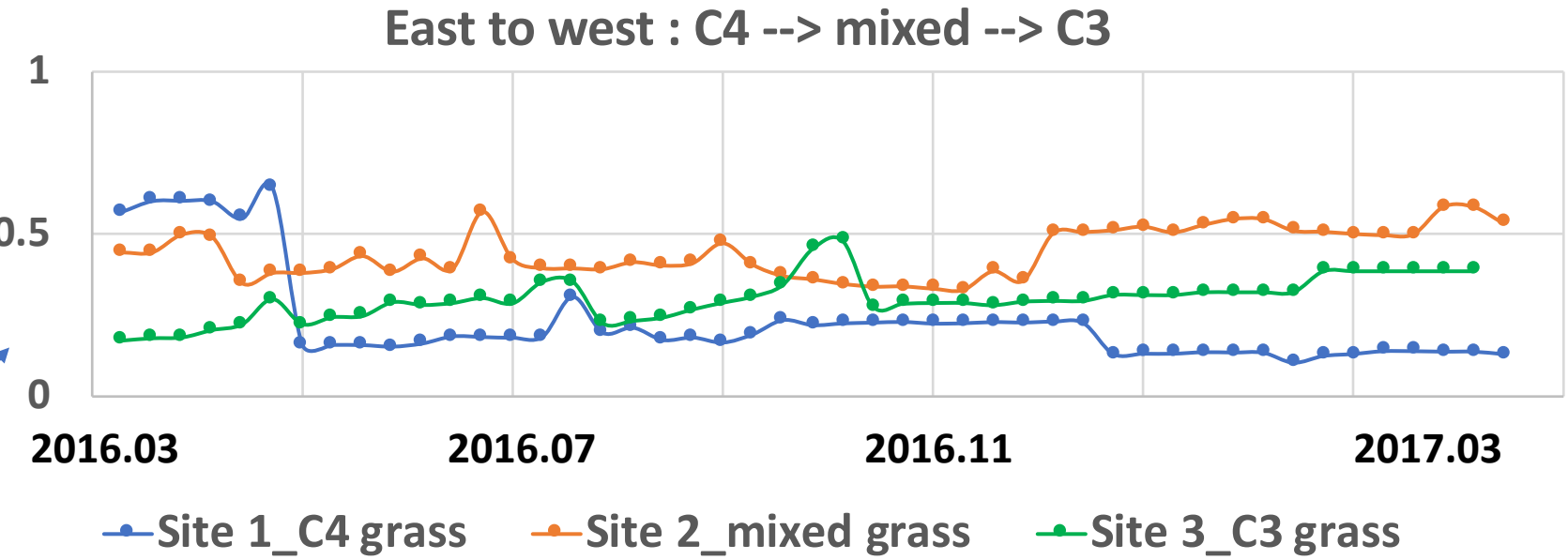
- **Spring (C3)**
- **Autumn (C4)**
- **Both (mixed)**

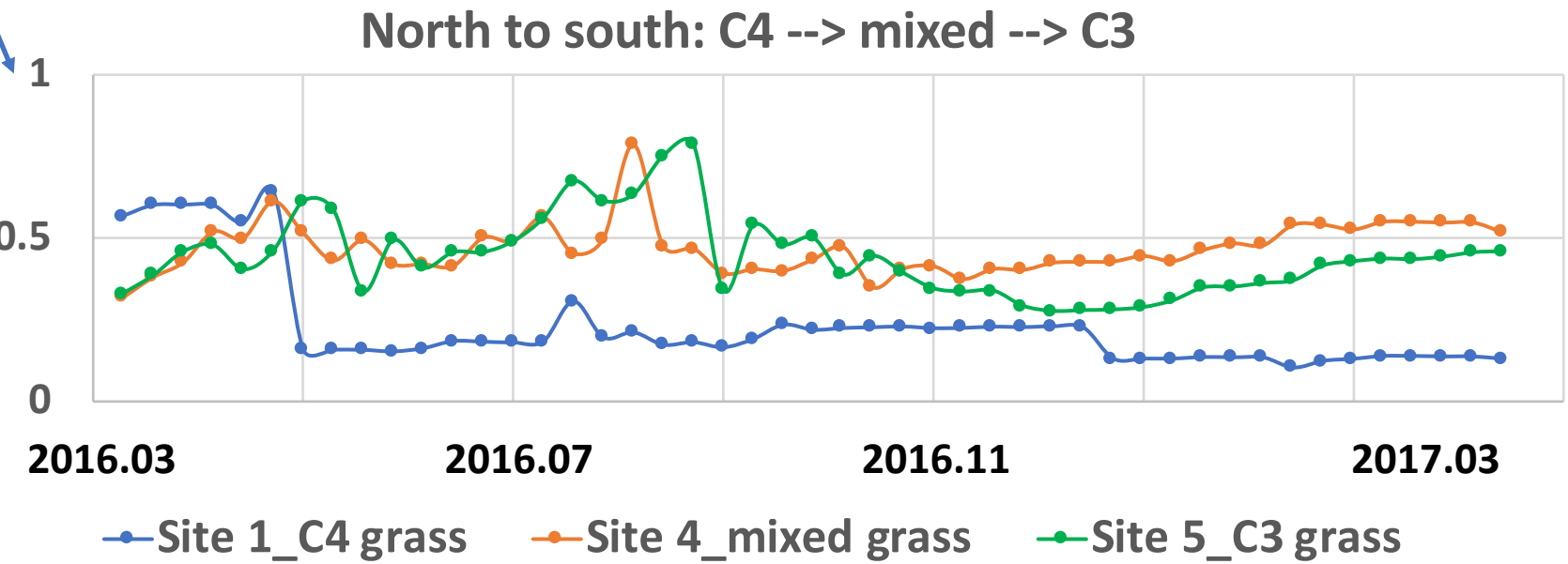
❖ Sentinel-2 (10m)



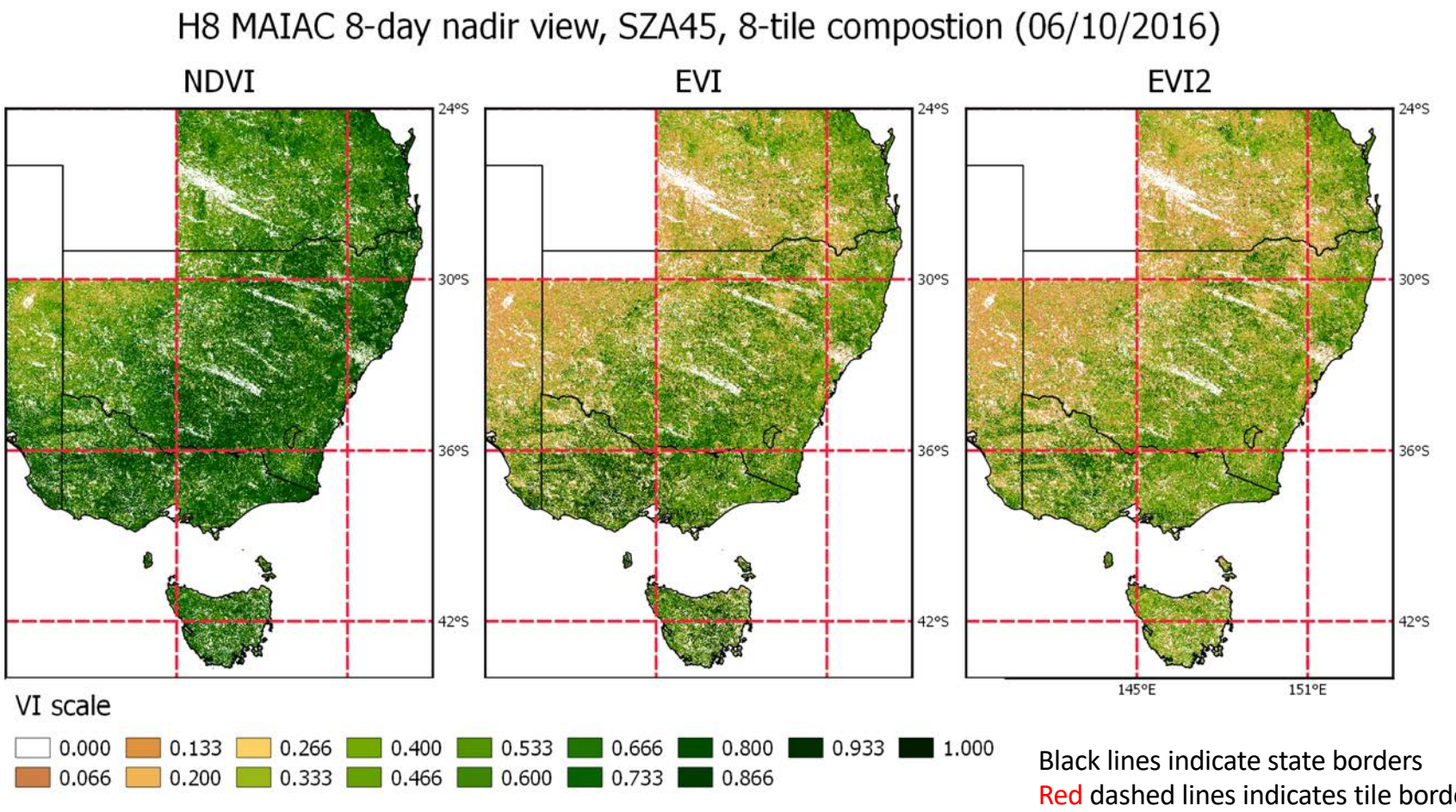
Himawari-8 EVI





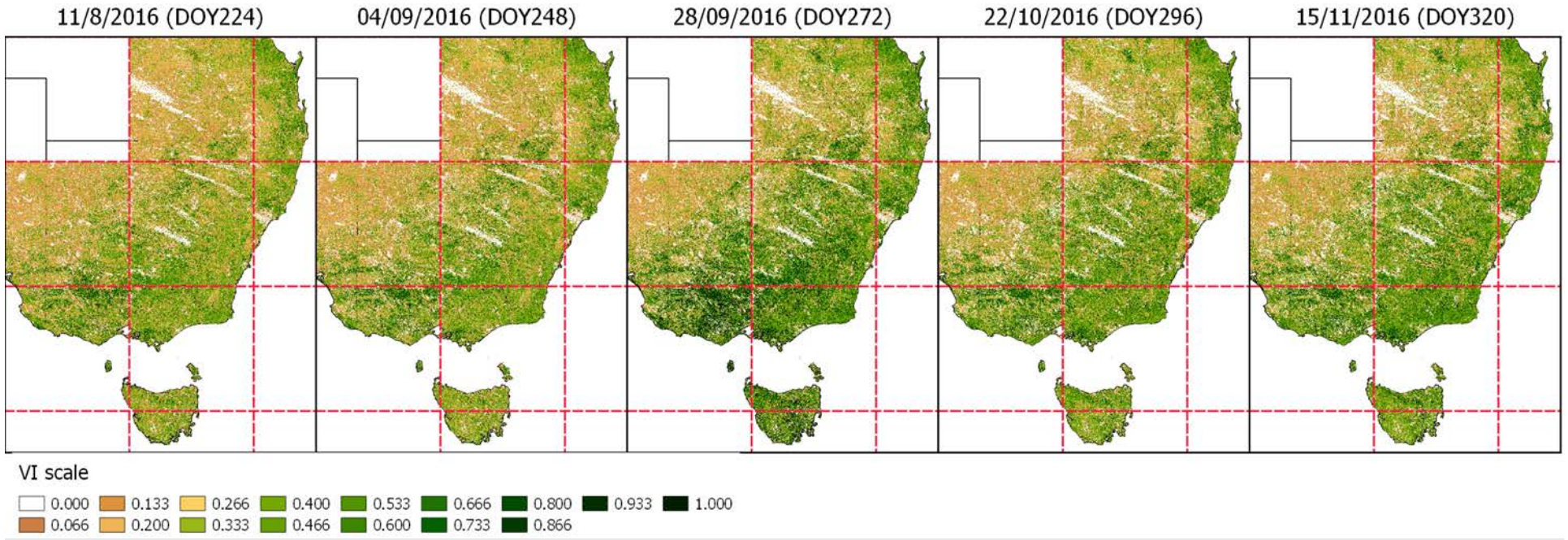


Himawari-8 Daily Reflectance & VIs



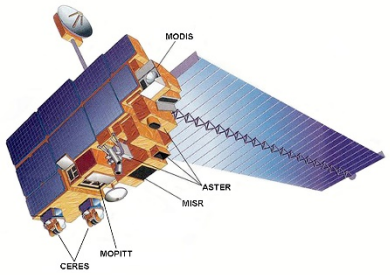
Black lines indicate state borders
Red dashed lines indicates tile border

H8 MAIAC EVI2 from 11/8 – 15/11/2016 (SZA45, 8-tile composition)



Validation of phenology product with phenocam

Validate phenology product with phenocam



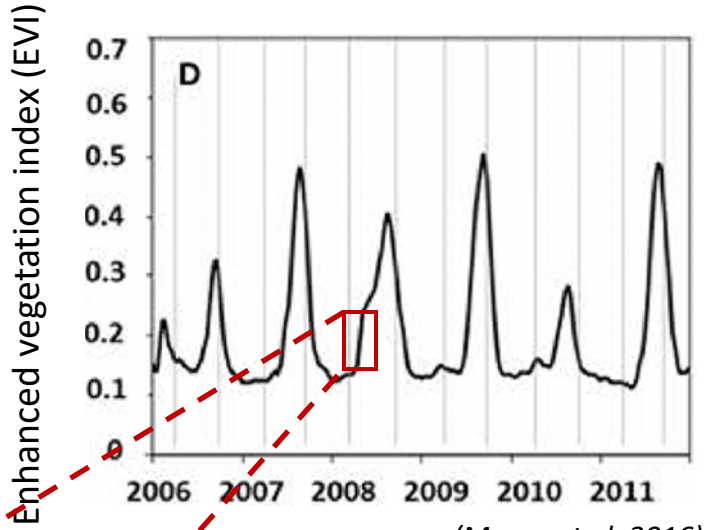
MODIS

MODerate resolution Imaging Spectrometer

Temporal resolution: 8 days

Spatial resolution: 250 m

Background



(Moore et al. 2016)

Sentinel - 2

Temporal resolution: 5 days

Spatial resolution: 10 m

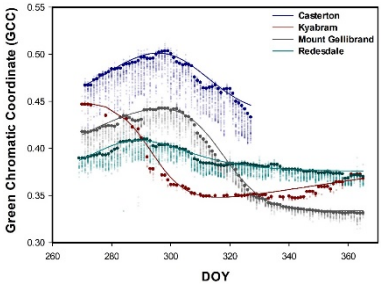
Himawari - 8

Temporal resolution: 10 min

Spatial resolution: 1000 m

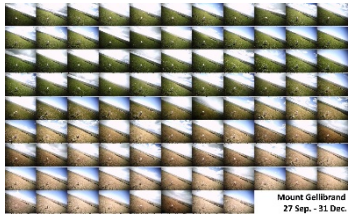
?

EVI



Phenocam GCC

……



Phenocam images

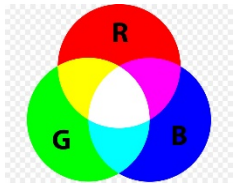
Validation

Phenocam sites in Australia

❖ Current phenocam sites:

City / State	Phenocam sites	Time of deployment
Brisbane	2	2018.07
Sydney	1	2018.07
Victoria	4	2017.09

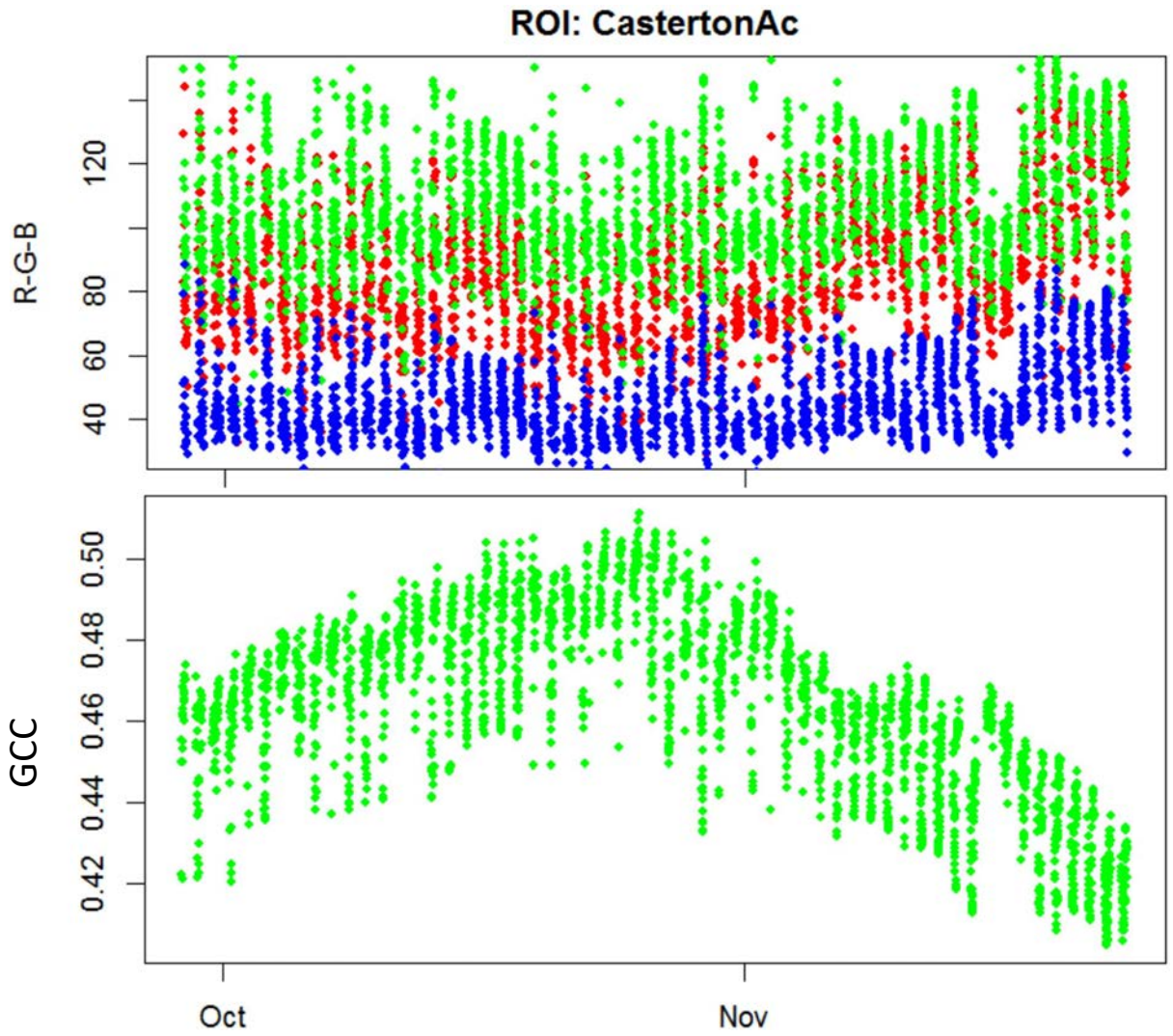
Quantitative analysis of phenocam imagery



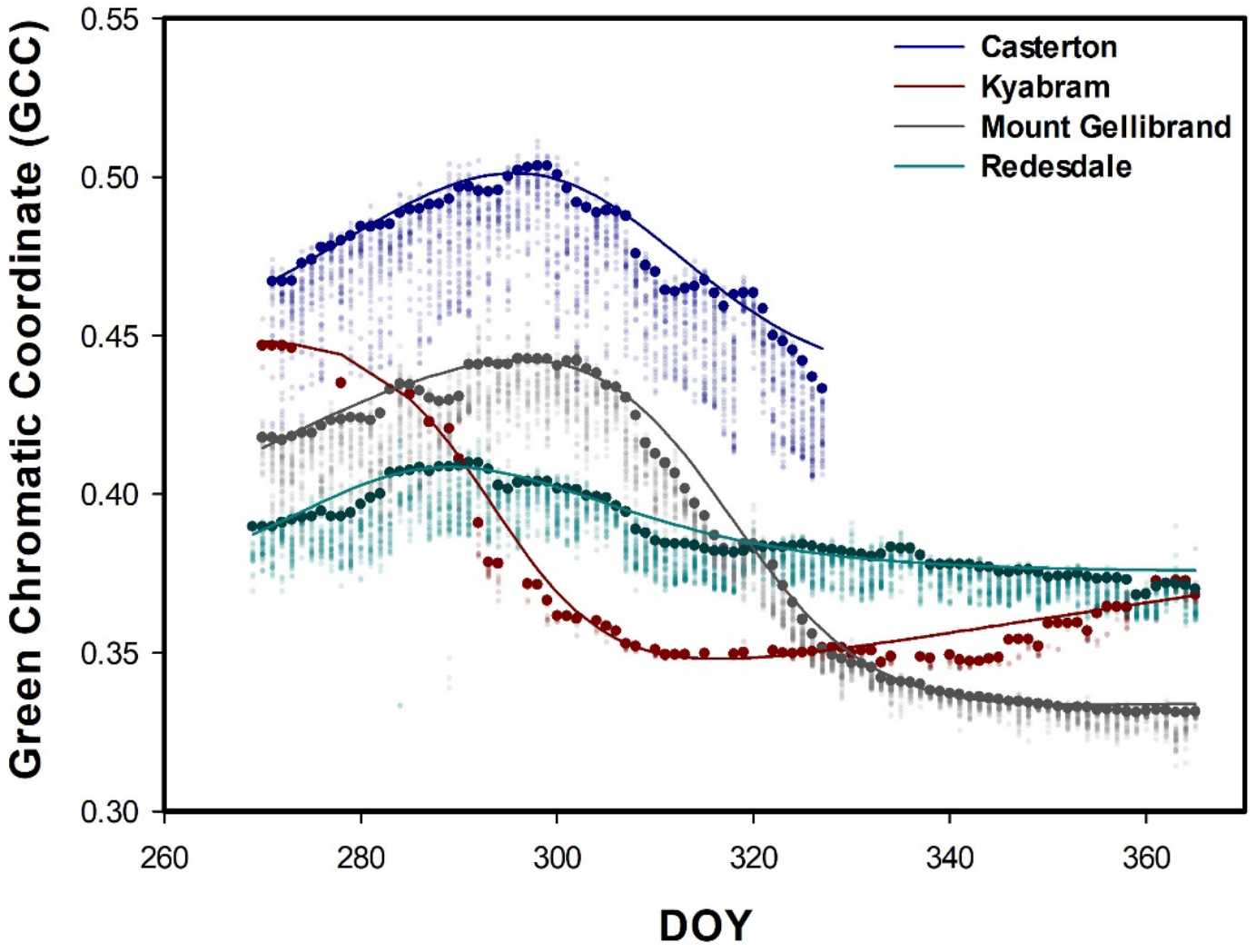
RGB Triplet
(R_{DN}, G_{DN}, B_{DN})

Green chromatic coordinates (GCC) = $\frac{G}{(R+G+B)}$

Vegetation "Greenness"

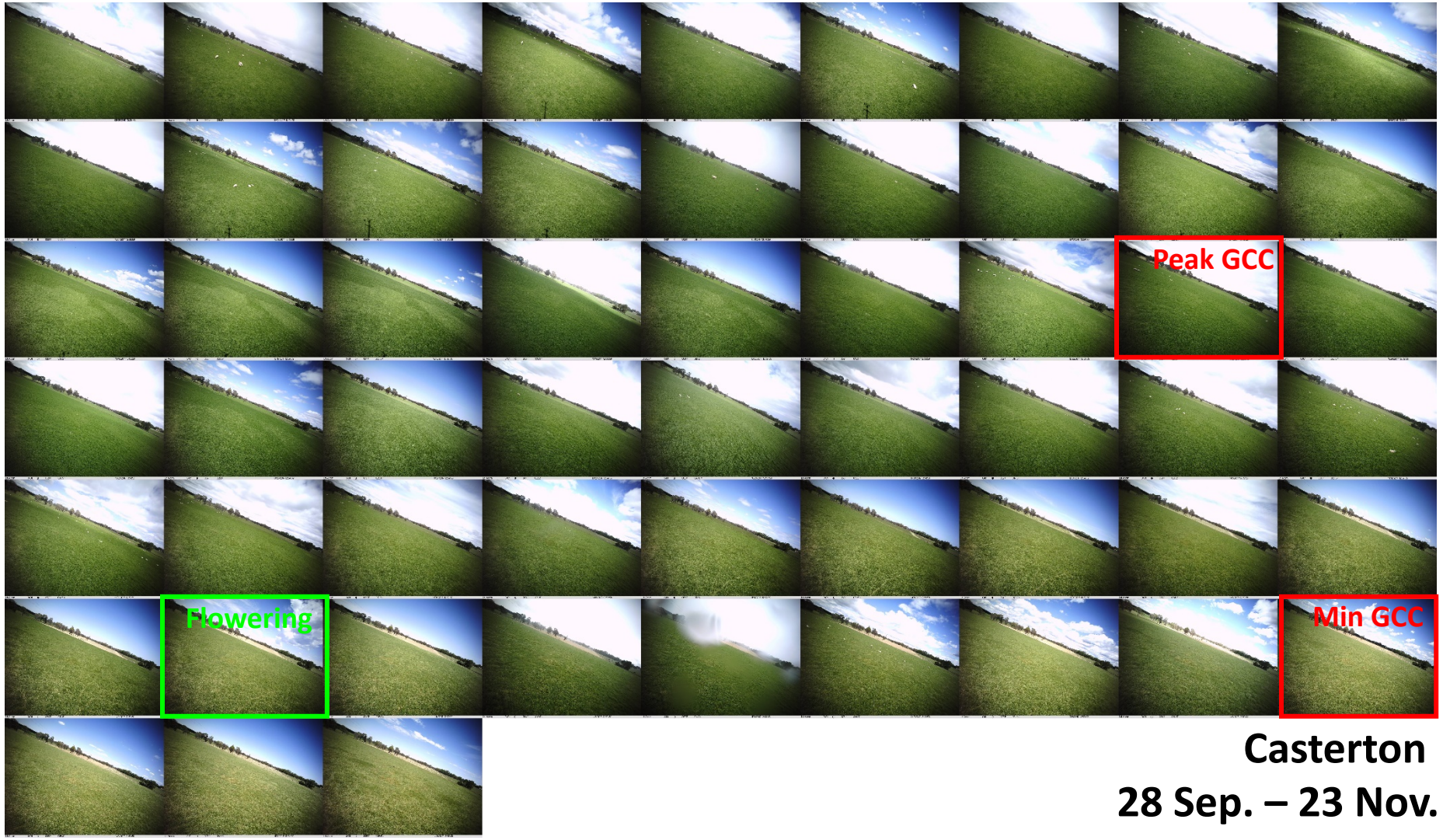


GCC profiles at Victoria sites



- **Significant variations in the GCC profiles**
  - greenness amplitude
  - greenness peaks
  - curing

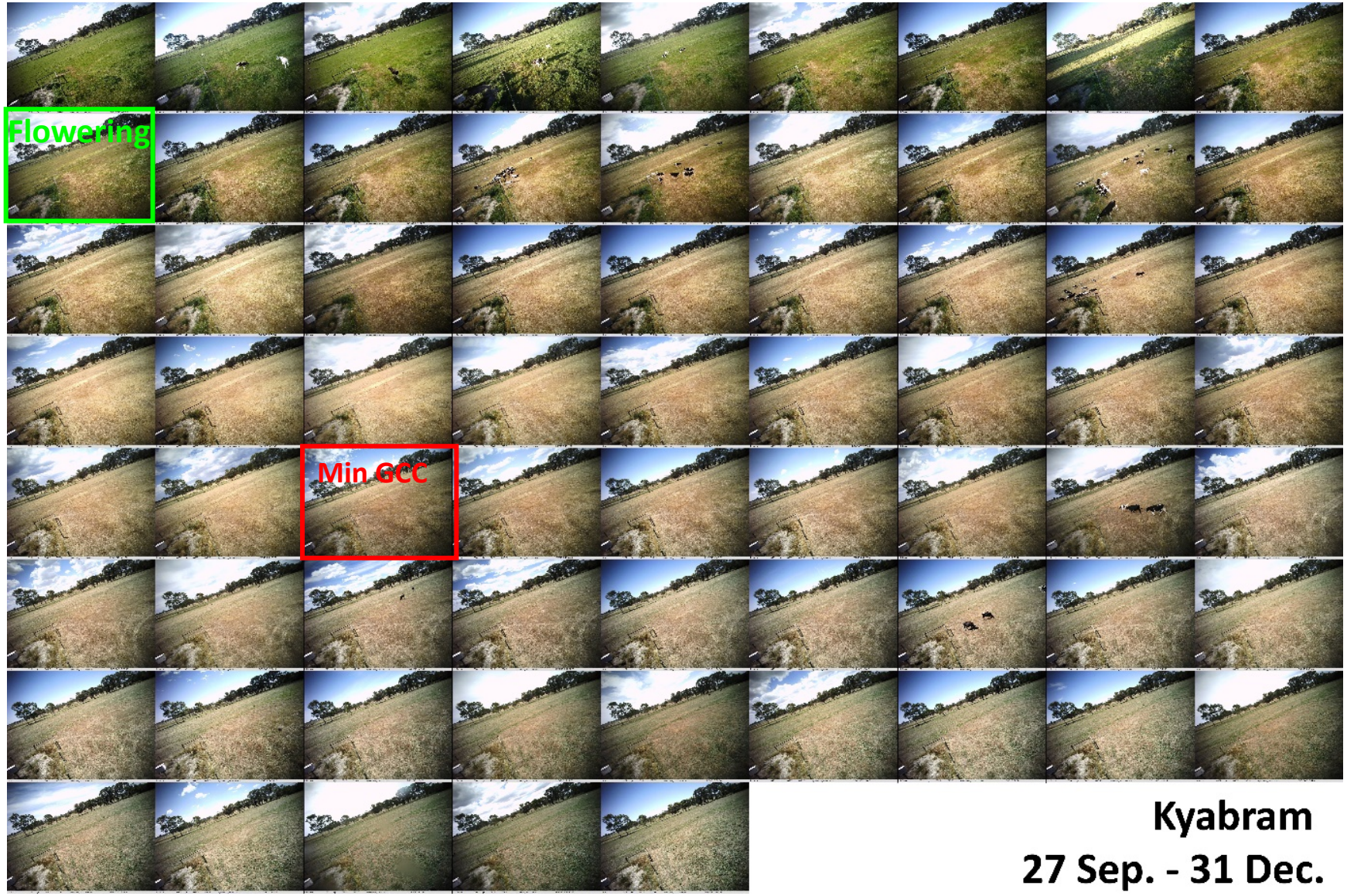
Montage of images at Casterton



Casterton
28 Sep. – 23 Nov.

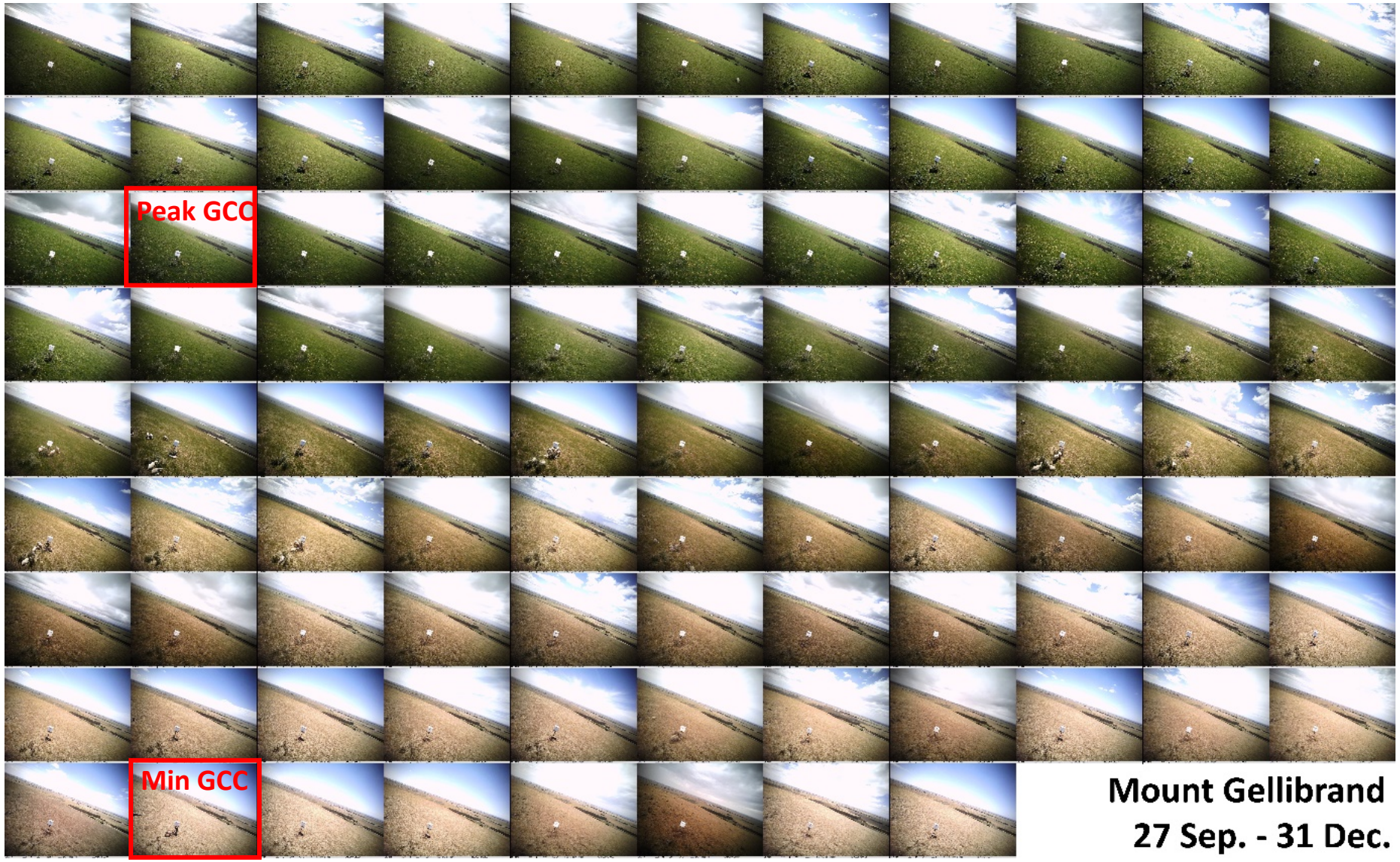
- **Peak GCC**: 0.504, 23 Oct.
- **Min GCC**: 0.433, 20 Nov.
- **Flowering**: 13 Nov.

Montage of images at Kyabram



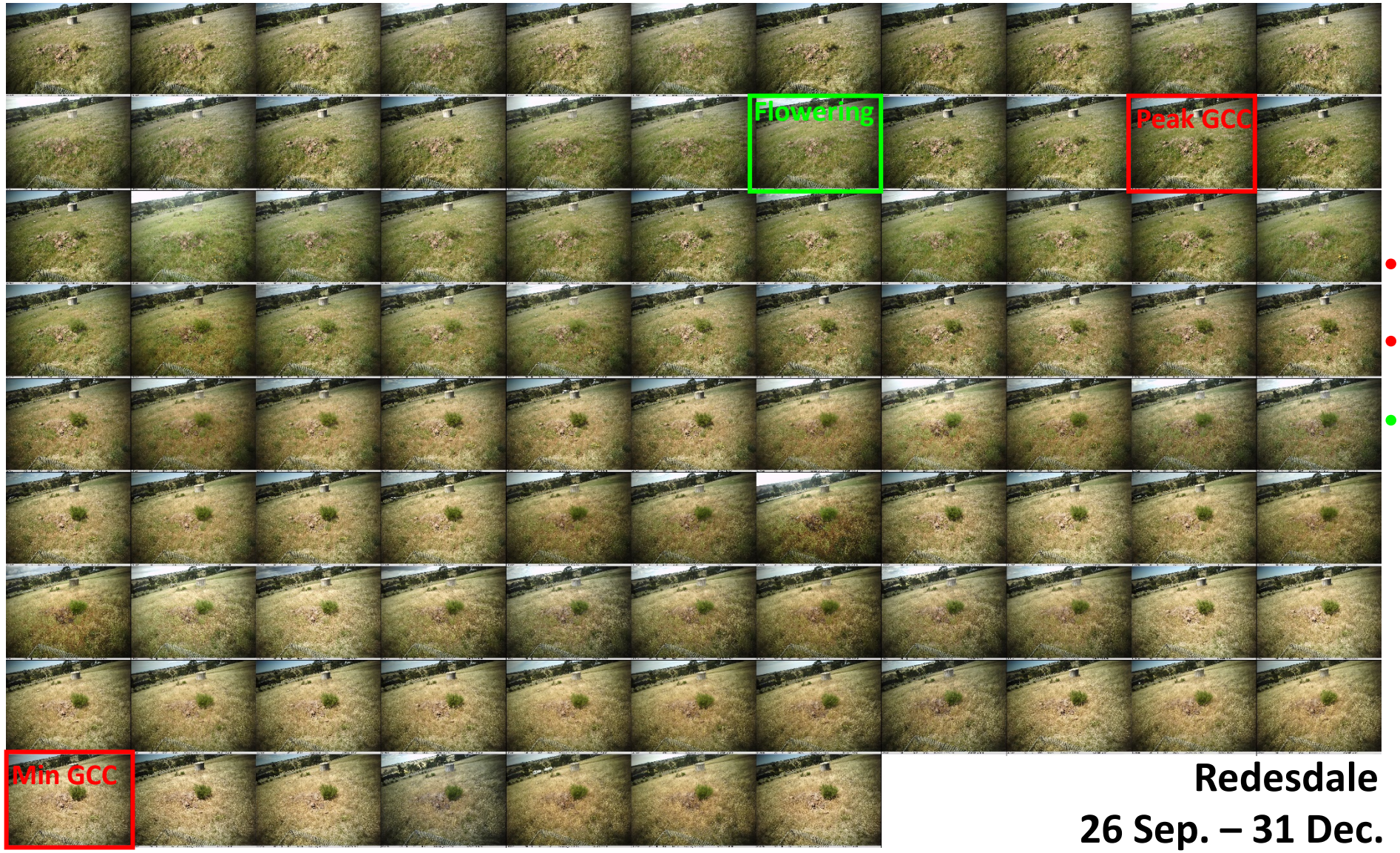
- **Min GCC**: 0.347, 26 Nov.
- **Flowering**: 19 Oct.

Montage of images at Mount Gellibrand



- **Peak GCC**: 0.443, 20 Oct.
- **Min GCC**: 0.331, 25 Dec.

Montage of images at Redesdale



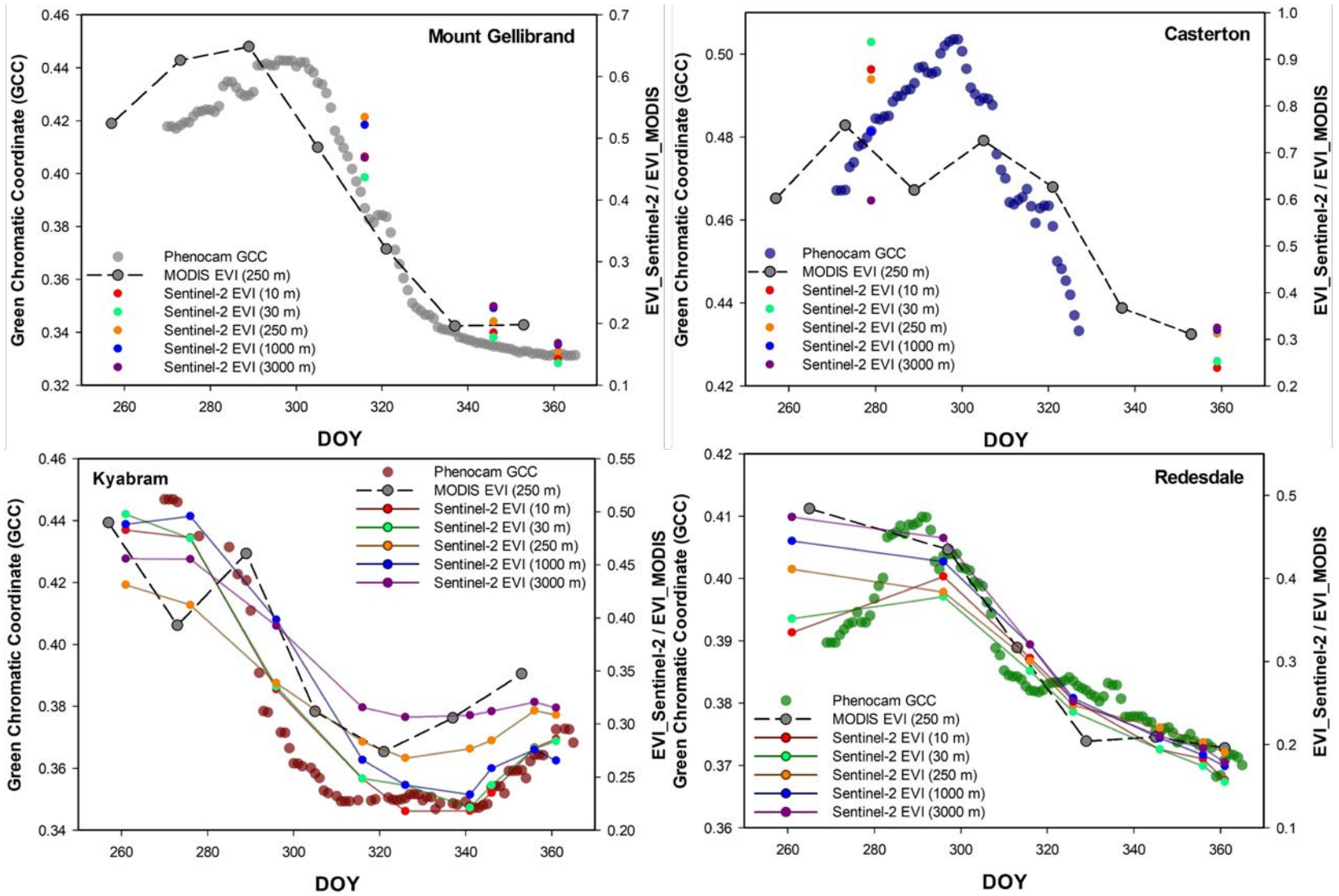
Redesdale

26 Sep. – 31 Dec.

- **Peak GCC**: 0.410, 16 Oct.
- **Min GCC**: 0.368, 25 Dec.
- **Flowering**: 13 Oct.

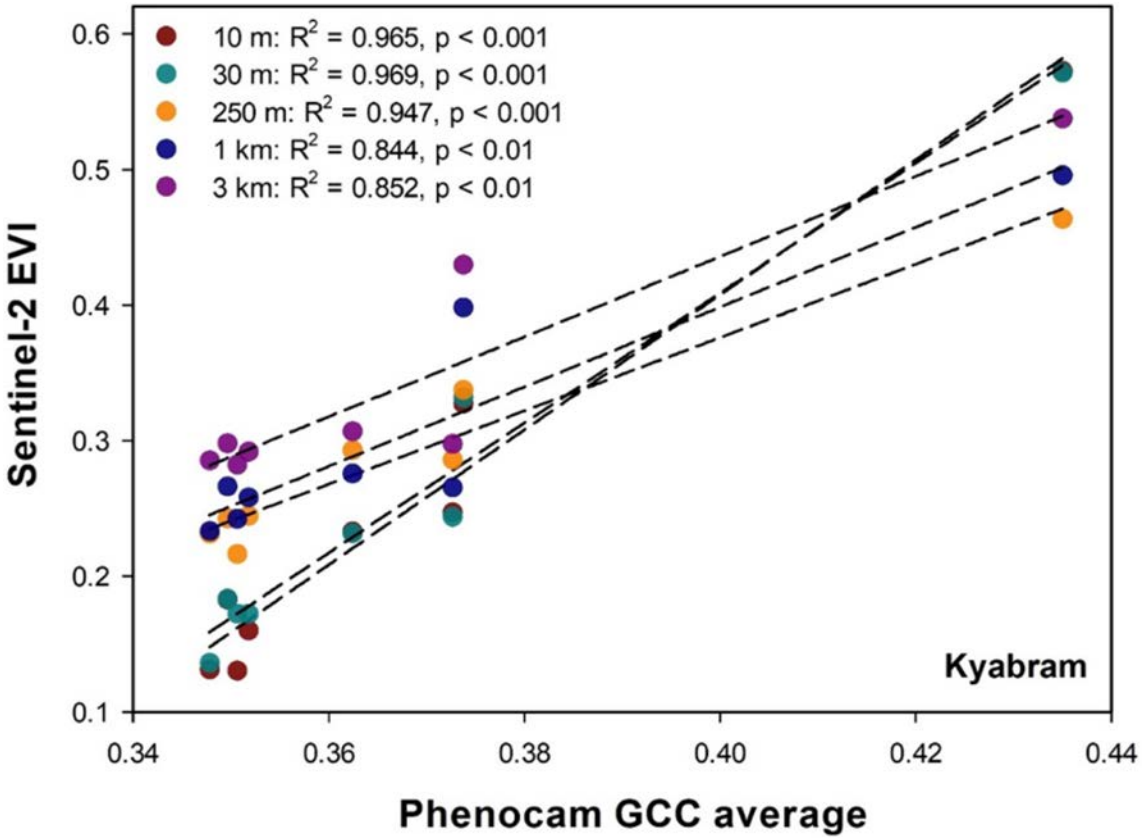
Satellite EVI vs phenocam GCC

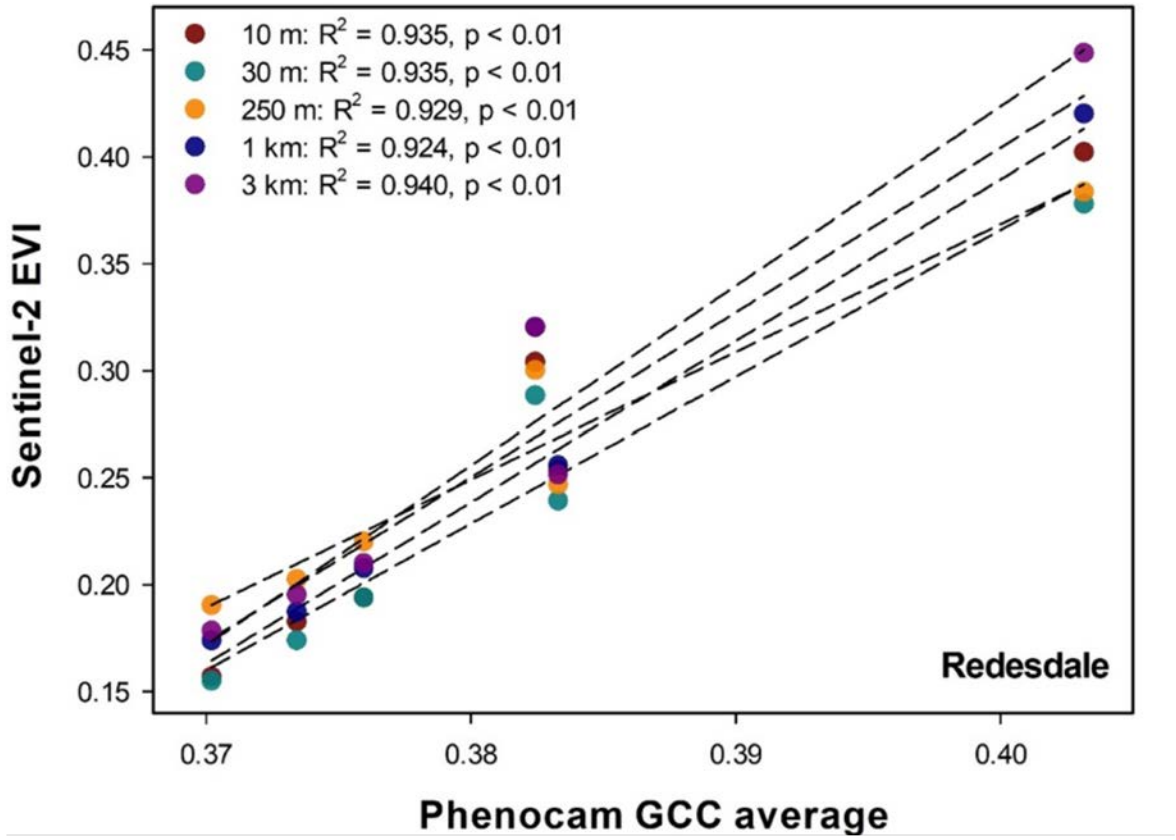
- The variations of Sentinel-2 and MODIS EVI are of significant consistency with phenocam GCC.
- Sentinel-2 with higher temporal resolution better captures grass phenology changes than MODIS.



Satellite EVI vs phenocam GCC

- Sentinel- 2 EVI is significantly correlated with phenocam GCC.

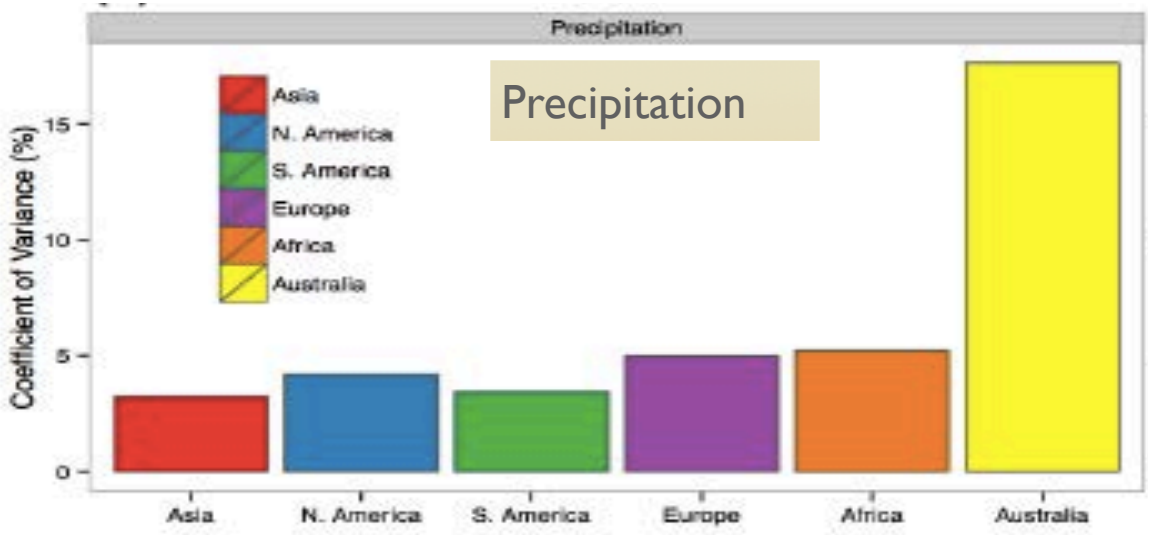


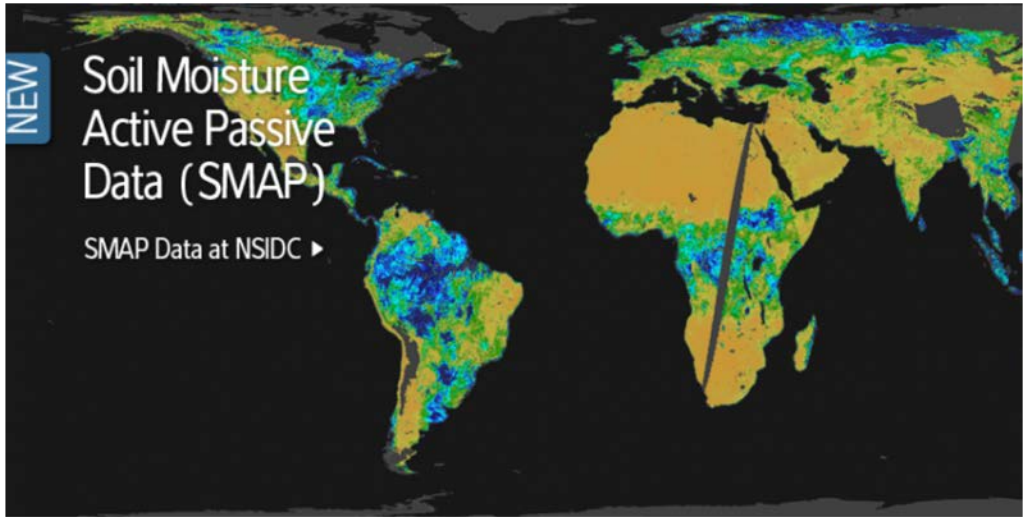


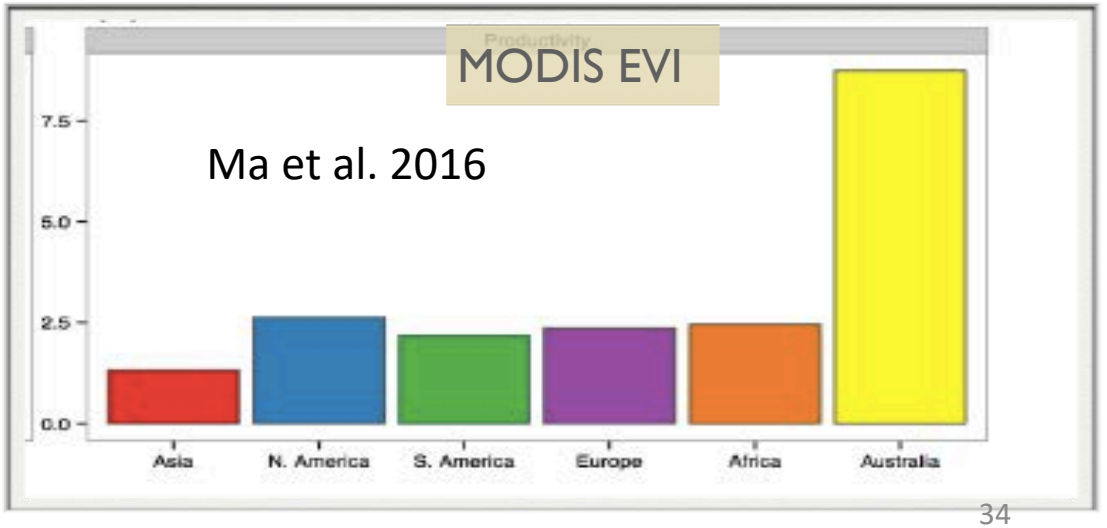
Drivers and controls of phenology

Soil Moisture impacts on vegetation dynamics in Australia

- Australia is the most climatic variable continent with precipitation driving vegetation activity in the extensive arid / semi-arid interior.
- Continuous soil moisture assessments from SMAP (Soil Moisture Active Passive) satellite mission offer new ways to understand vegetation dynamics.



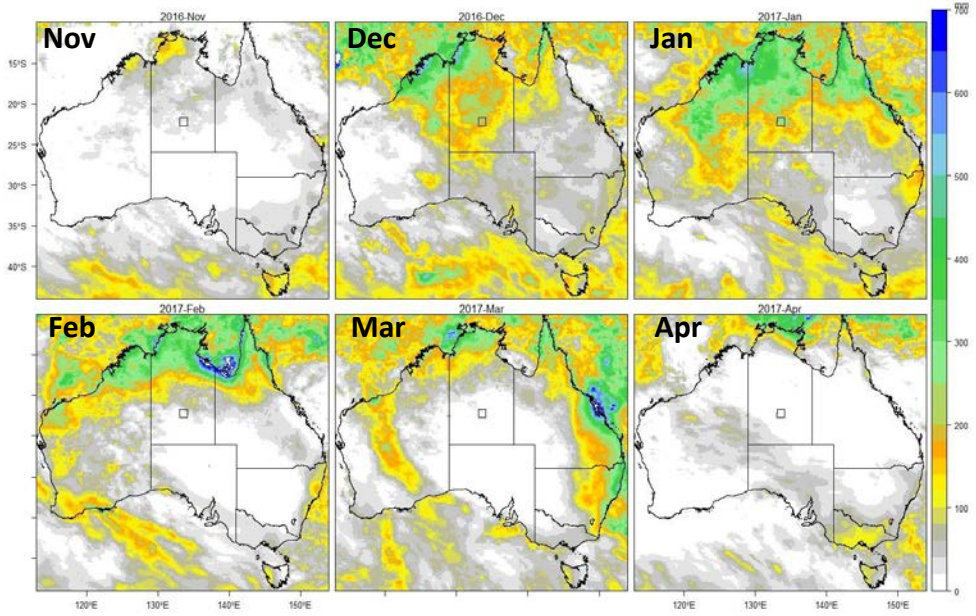




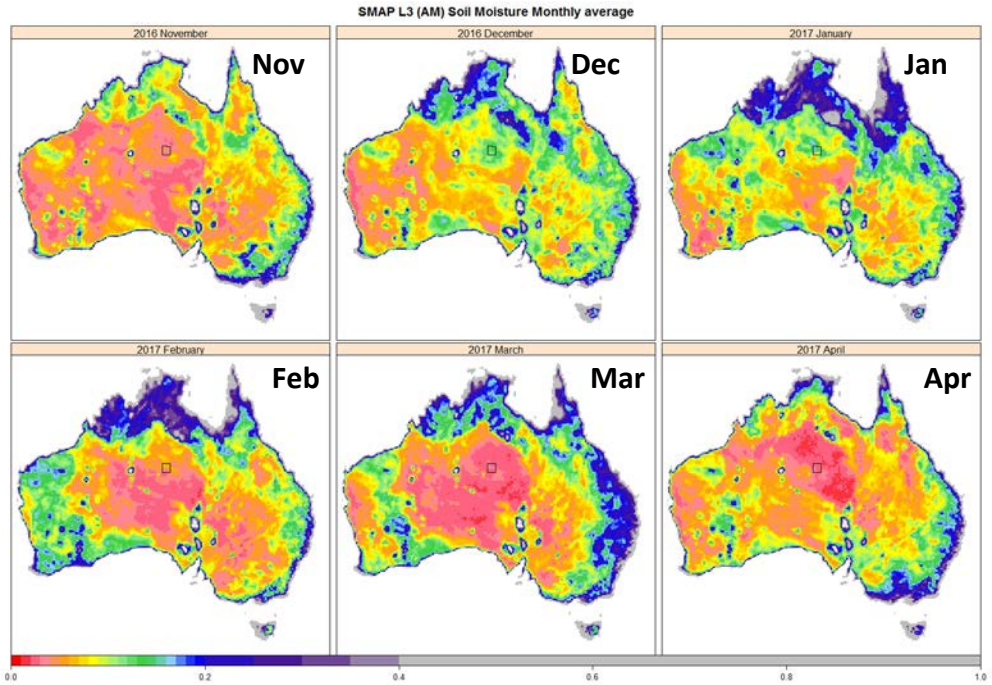
Central Australia semi-arid area wet pulse event

- Large areas of central Australia received more than 100-200 mm precipitation in December 2016 and January 2017.

❖ Monthly Precipitation during 2016-2017 Monsoon Season (IMERG)



❖ SMAP soil moisture monthly average during 2016-2017 Monsoon Season

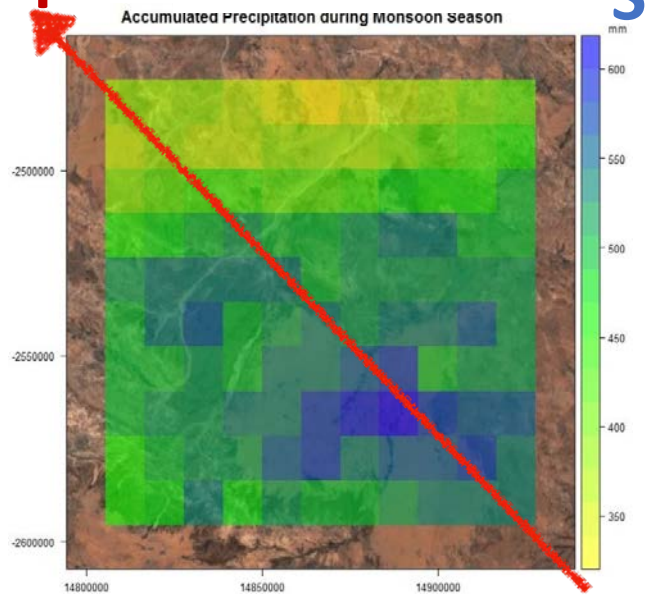


Soil Moisture & Precipitation

- Soil moisture spatial patterns align with soil types

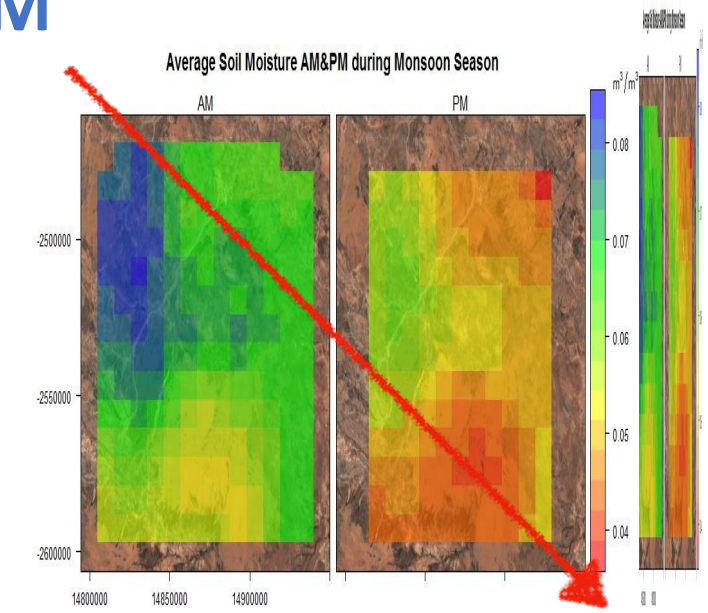
Low Precip

Accumulative Precipitation

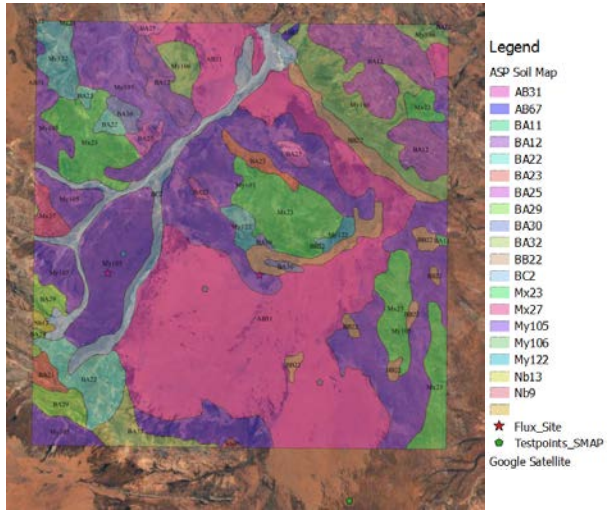


High SM

Averaged Soil Moisture



Soil Map



High Precip

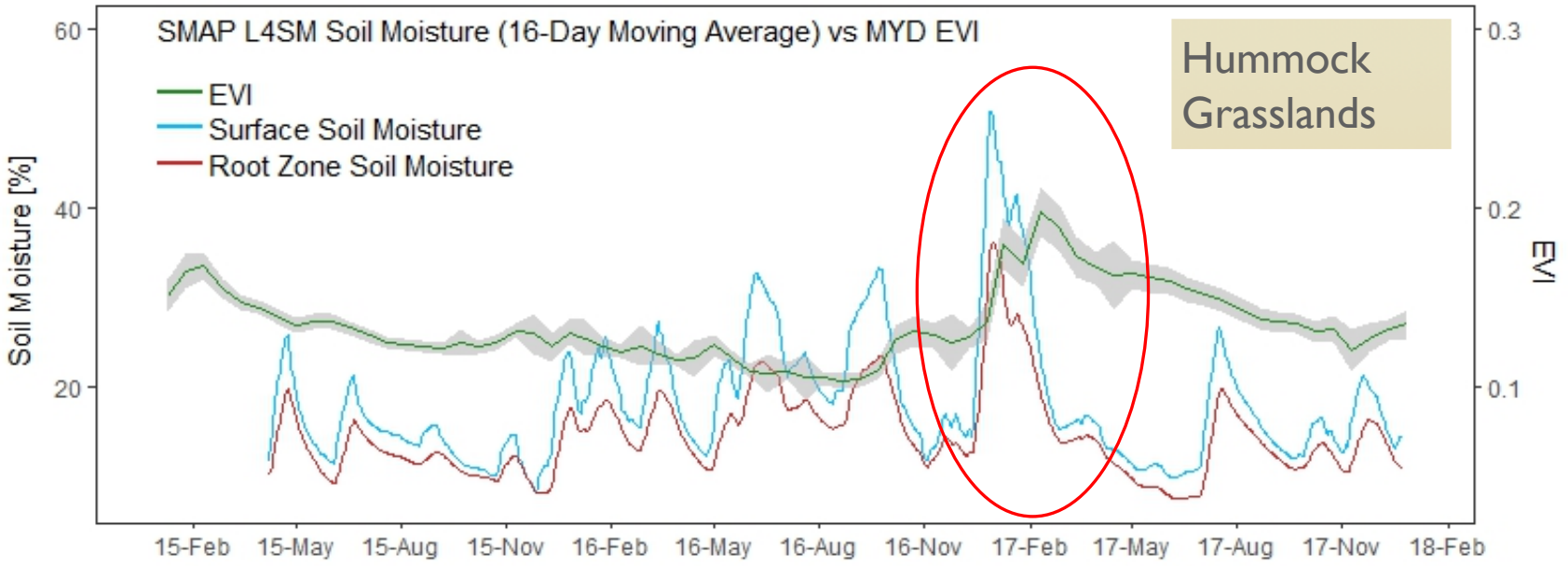
Low SM

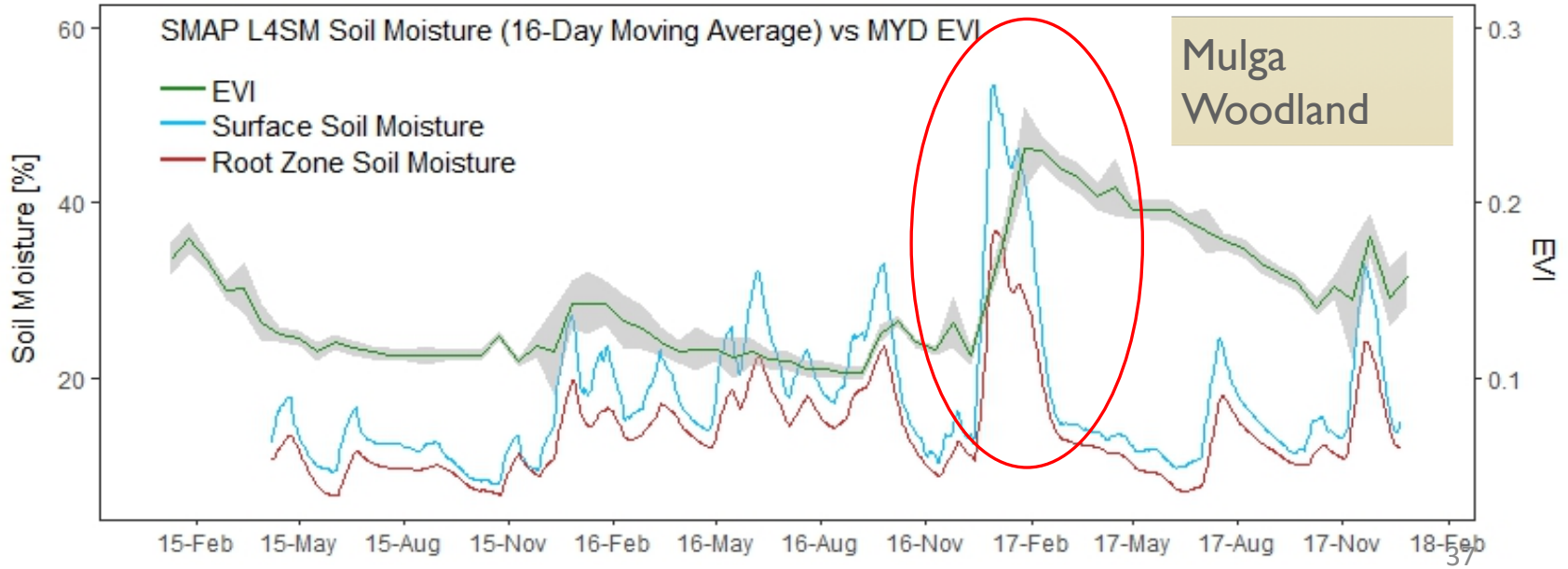
Central Australia semi-arid area

- SMAP Level 4 product Soil moisture vs MODIS EVI

Mulga woodland is more responsive than Hummock grassland to 2017 wet event

The wet event sustained Mulga woodland and Hummock grass functional types for >1 year, despite low surface soil moisture, and Hummock grass showed a 24 month phenology cycle. Are there 'leaf-on' or 'leaf-off SM threshold controls?





Central Australia semi-arid area

- SMAP Level 4 product GPP vs MODIS EVI

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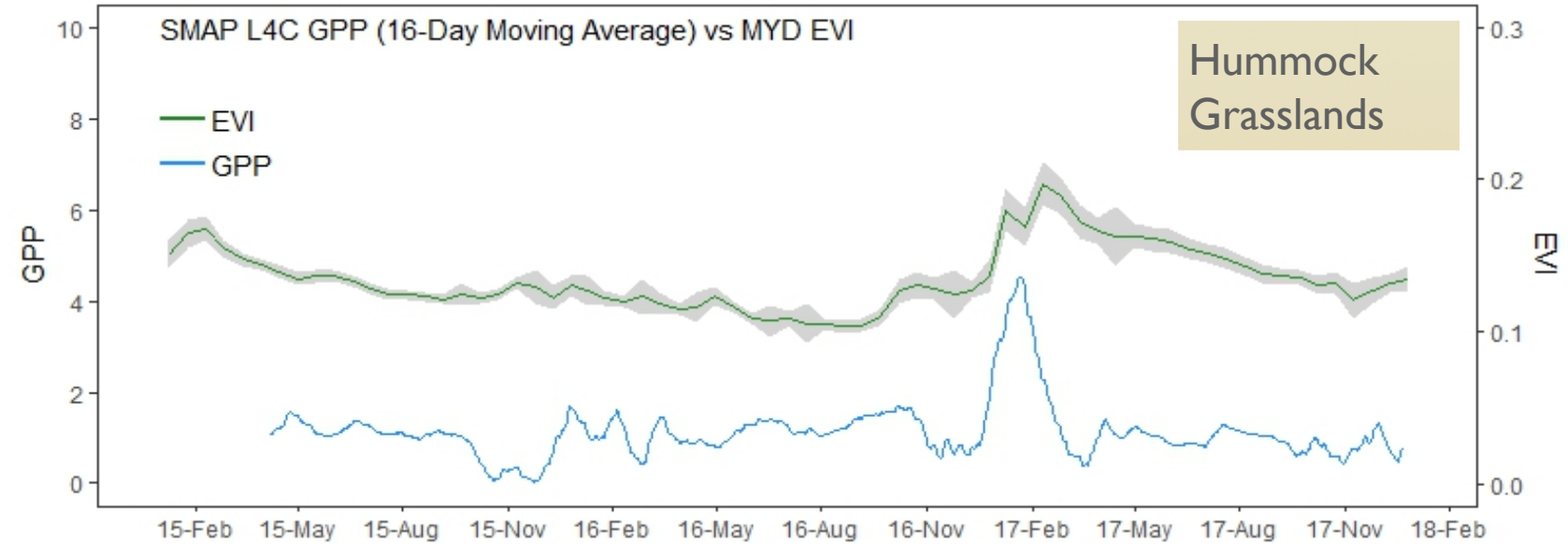

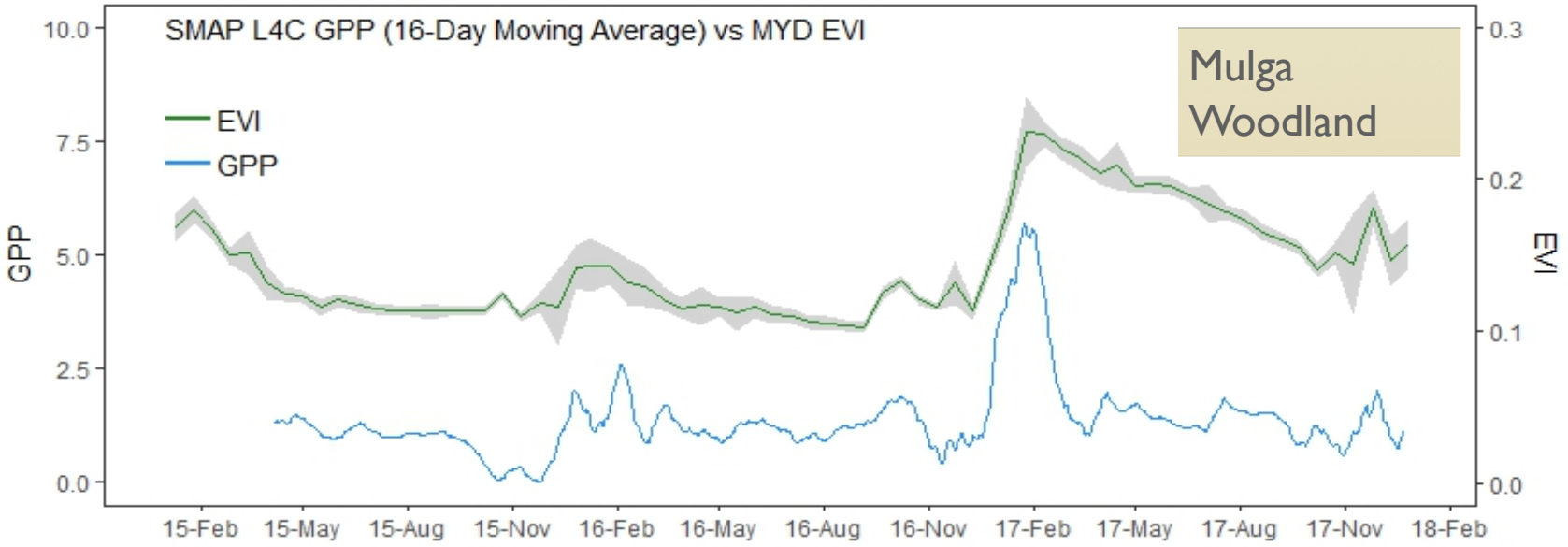

Conclusions

Conclusions

1. MODIS transferring to VIIRS:

- MODIS: 250m, 500m, 1km, 0.05 deg resolution vegetation index products
- VIIRS: 500m, 1km, 0.05 deg resolution vegetation index products

Phenology products considered to be developed at these scale

2. Sentinel-2 and Himawari-8:

- Trial experimental sub-continental phenology metrics derived from Sentinel-2 at 10 m resolution over select areas
- Trial Himawari-8 to utilise daily measures of spectral greenness indices and refine phenology timing events to 1-day precision.

3. SMAP:

- Drivers and controls of phenology

Thank You

Contact:
Alfredo.Huete@uts.edu.au
Qiaoyun.Xie@uts.edu.au

UTS
UNIVERSITY OF TECHNOLOGY SYDNEY