Investigating climate impacts on landscape phenology and biodiversity using multi-sensor earth observations

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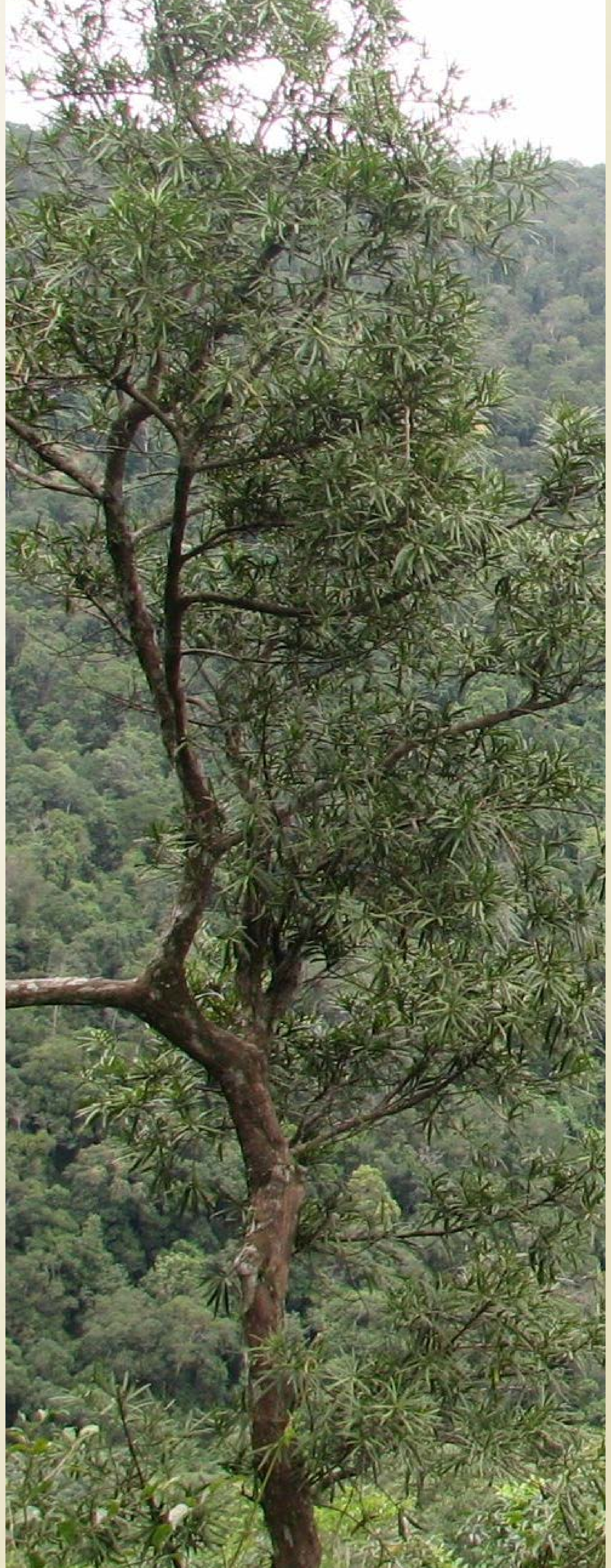
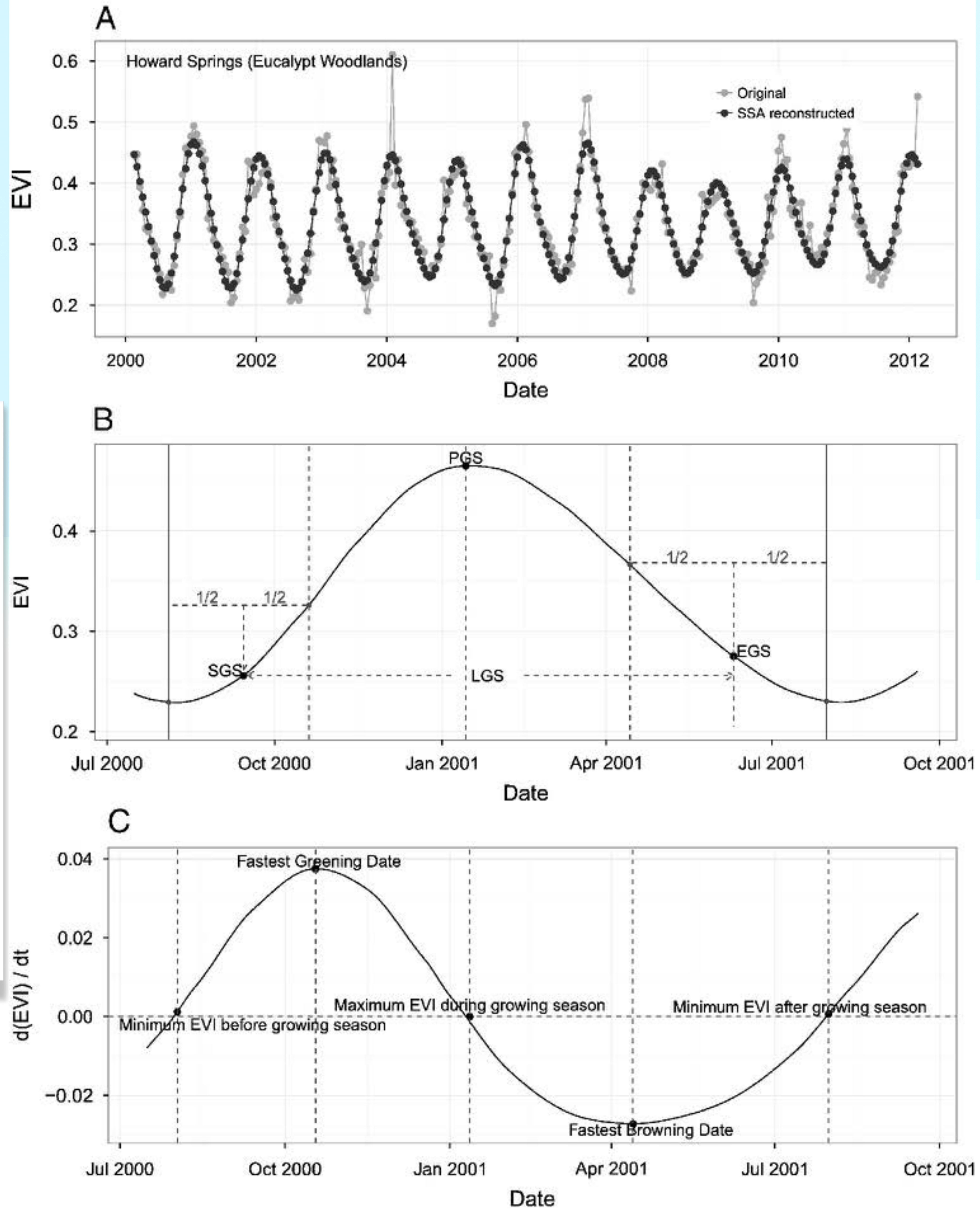
Satellite Phenology & Biome Seasonality

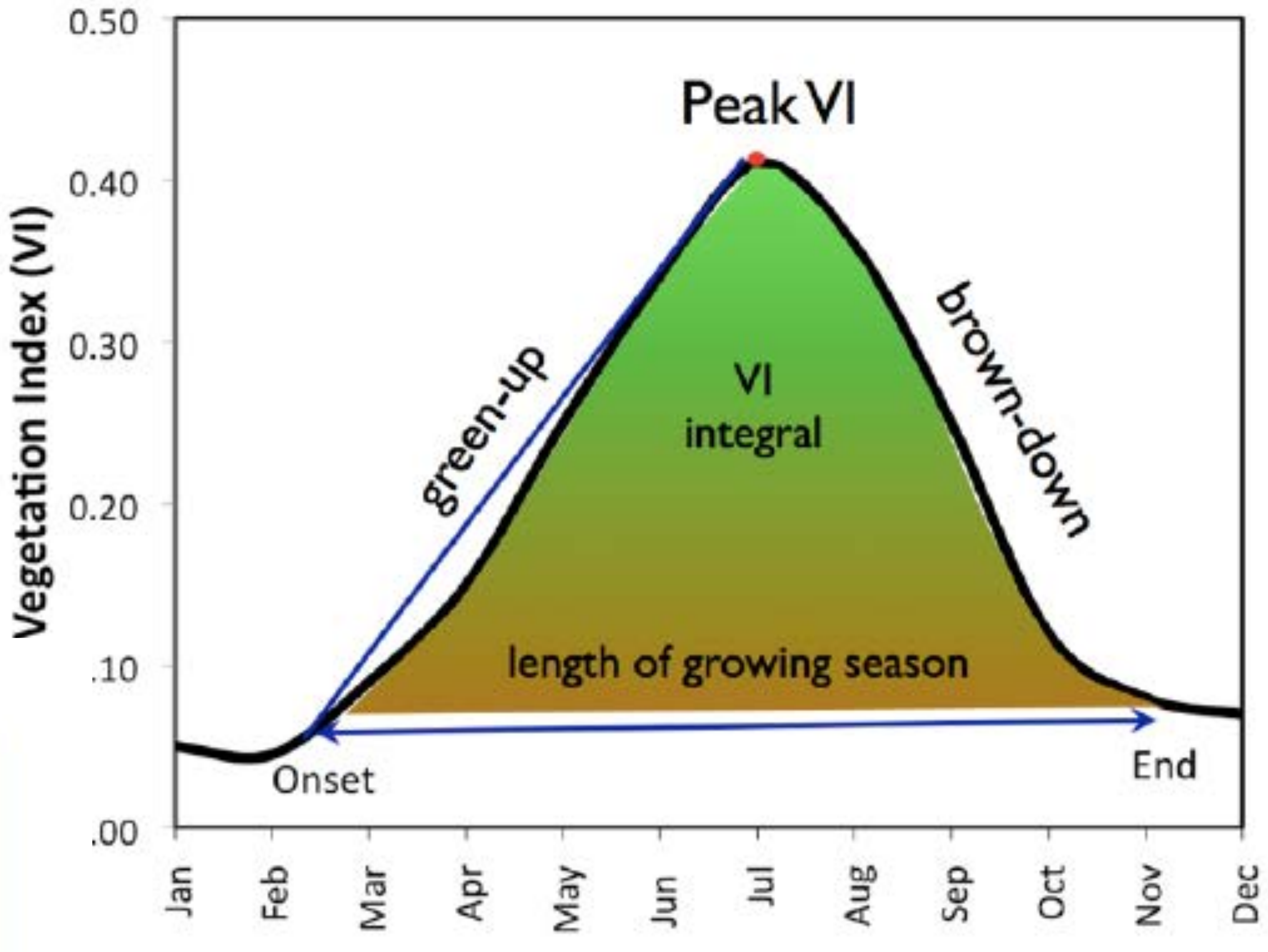
- Phenology “reflects” the interactions (responses, feedbacks) of organisms with their environment,
- Phenologic variations influence local biogeochemical processes, photosynthesis, water cycling, soil moisture depletion, and canopy physiology,
- Phenology is an important indicator of climate change, global change, and disturbance (anthropogenic signal),
- Phenological data and models are used in drought monitoring, wildfire risk assessment, archaeology, ecological forecasting.



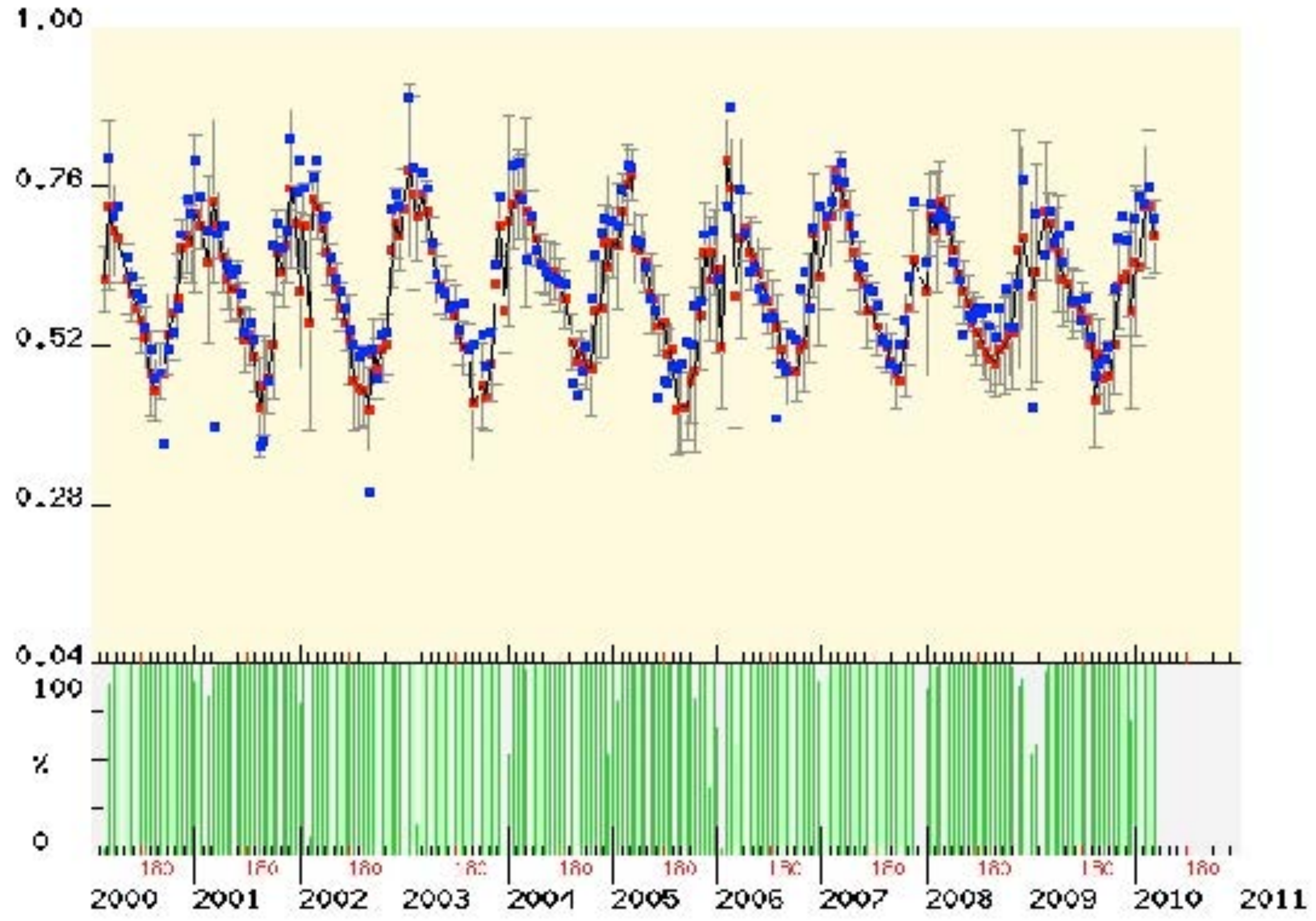
Introduction

- Different pixels have unique temporal fingerprints, due to species composition and environmental drivers/ controlling factors. Hence interactions of phenology profiles with biodiversity.





Satellite VI



Ma, X et al., 2013 RSE

Methods

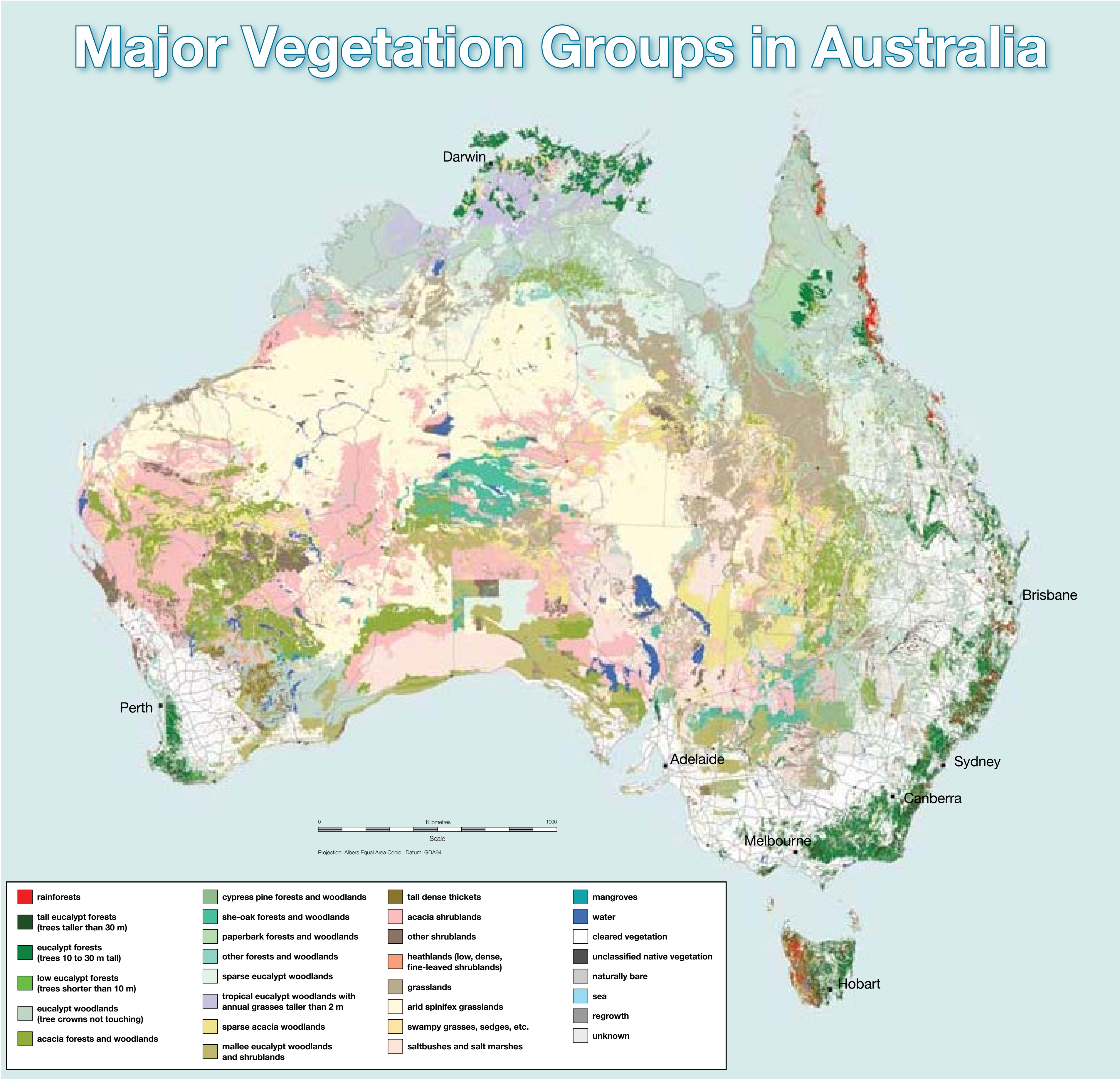
- - Multiple sensors needed encompassing spatial, temporal, and spectral domains
- - Coarse resolution, such as MODIS, VIIRS, Sentinel,
- - GEO-LEO combined for gap filling
- - Spatial resolution needed for validation, heterogenous patterns, multi-species, tree-grass (woody), biodiversity. Example of PlanetScope (Jin WU papers).
- - Hyperspectral relating spectral diversity with biodiversity.

Monitoring of Dryland Ecosystems

Eucalypt Open Woodlands (MVG 11)
Eucalypt Woodlands (MVG 5)

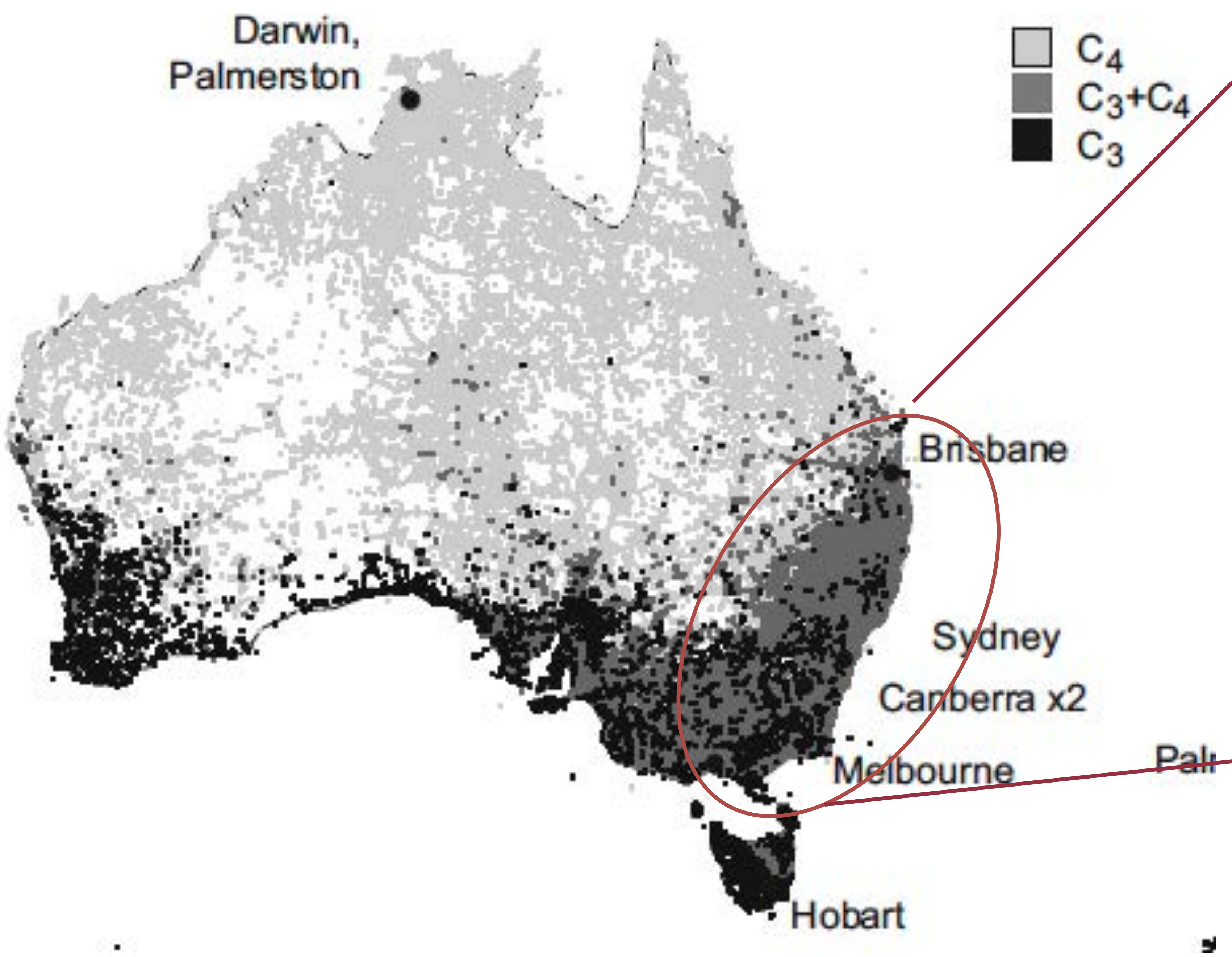
Hummock Grasslands (MVG 20)

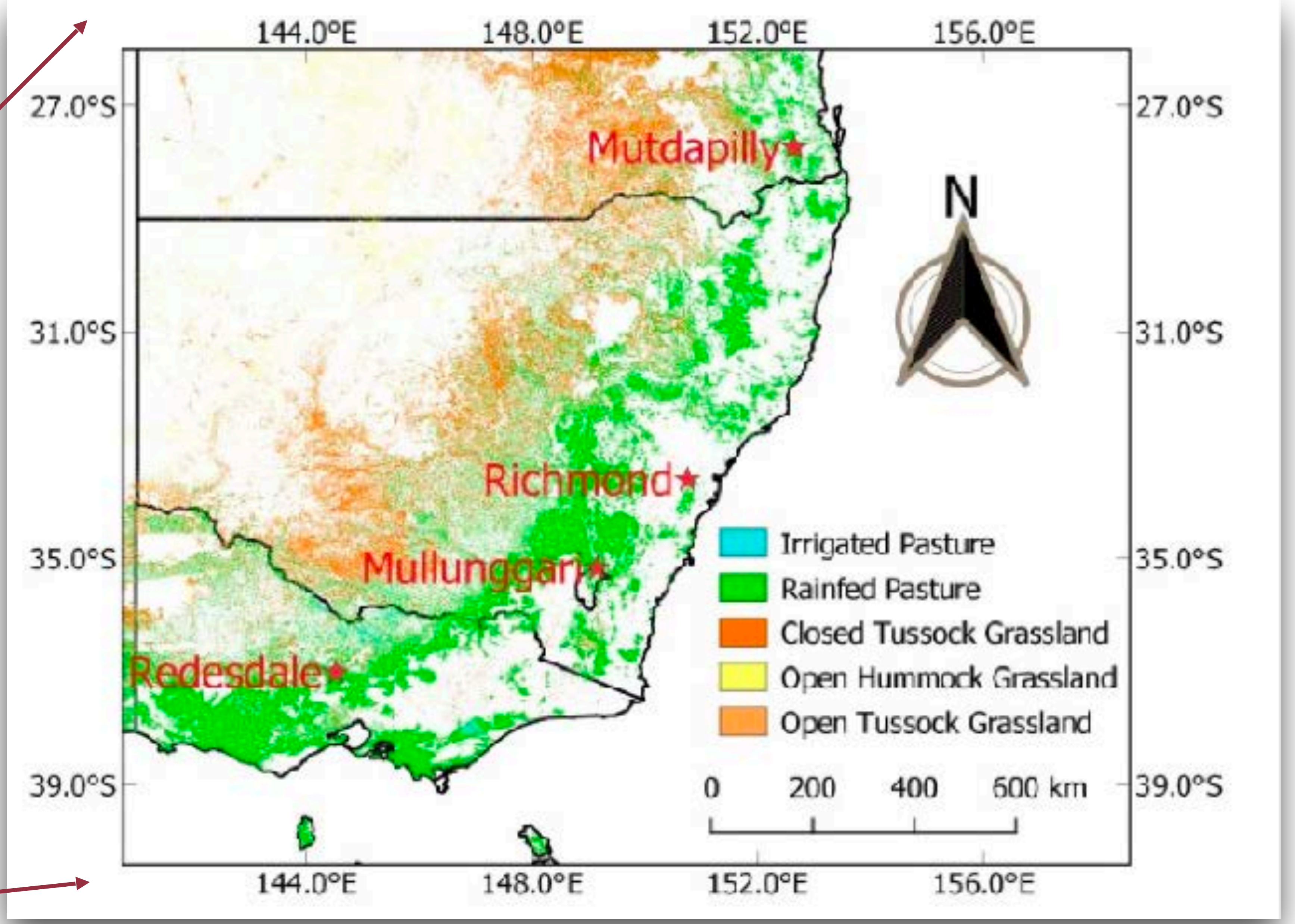
Eucalyptus terminalis, *Triodia basedowii* (lobed spinifex), *Acacia ligulata*, *Cassia nemophila*, north-west of Warri Gate, Qld



- Landscape consists of mixtures of woody C_3 and non-woody C_3, C_4 plants with unique temporal signatures and functional diversity.

Grasslands & Pastures in SE Australia





Dynamic Land Cover Data product (Geoscience Australia)

- Current C3- C4 grassland maps are generated from empirical meteorology of warm and cool season environments and/or citizen science.

Distribution of C3 and C4 grasses in Australia (Medek et al. Aerobiologia 2016)

Subtropical grasses (Chloridoideae)

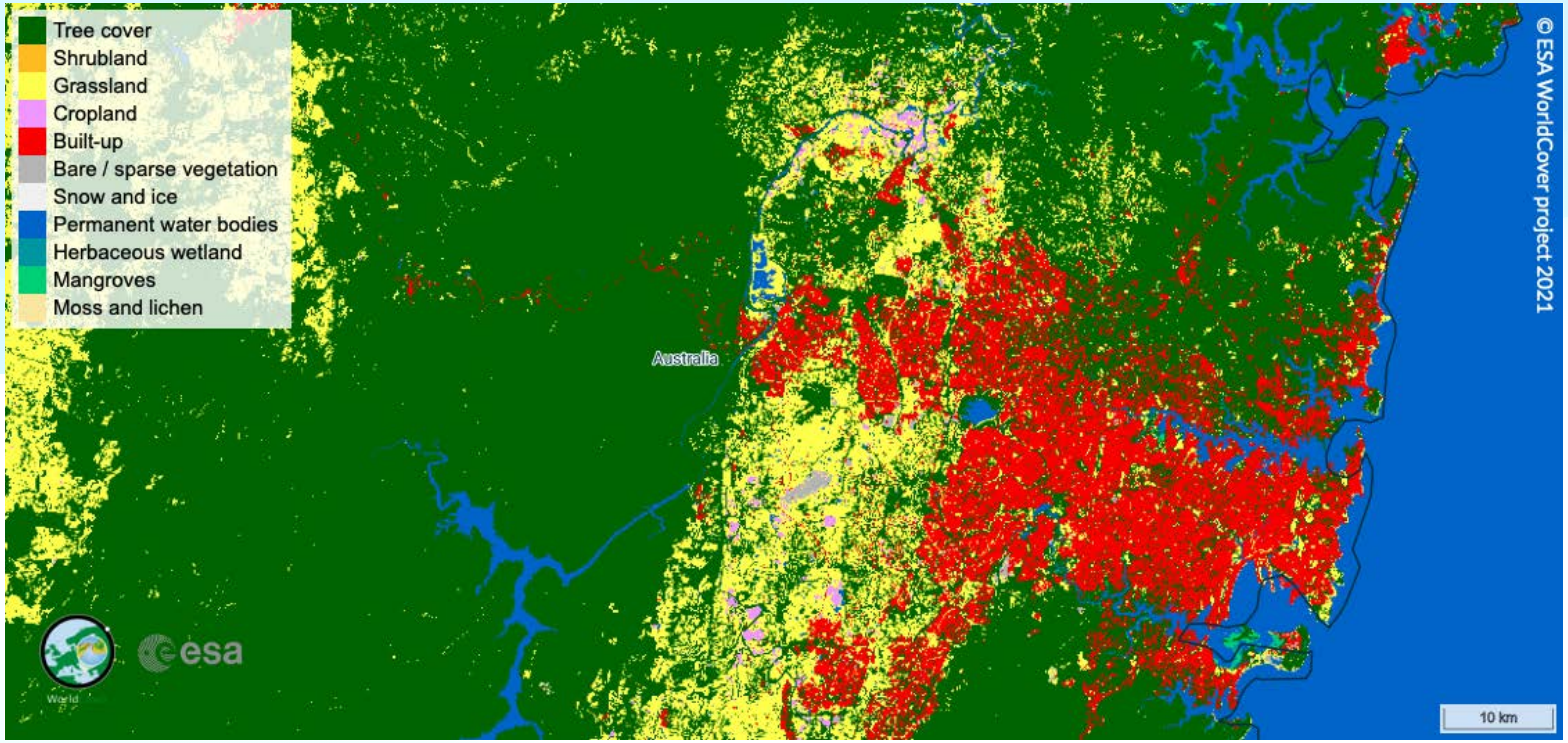
C_4 grasses

Poaceae family

Temperate grasses (Pooideae)

C_3 grasses

Sentinel 1, 2 derived WorldCover maps at 10m



Sentinel WorldCover maps
10m resolution
Uses both optical (Sentinel-2) and radar (Sentinel-1) to classify land cover types

Mapping Functional Plant Diversity

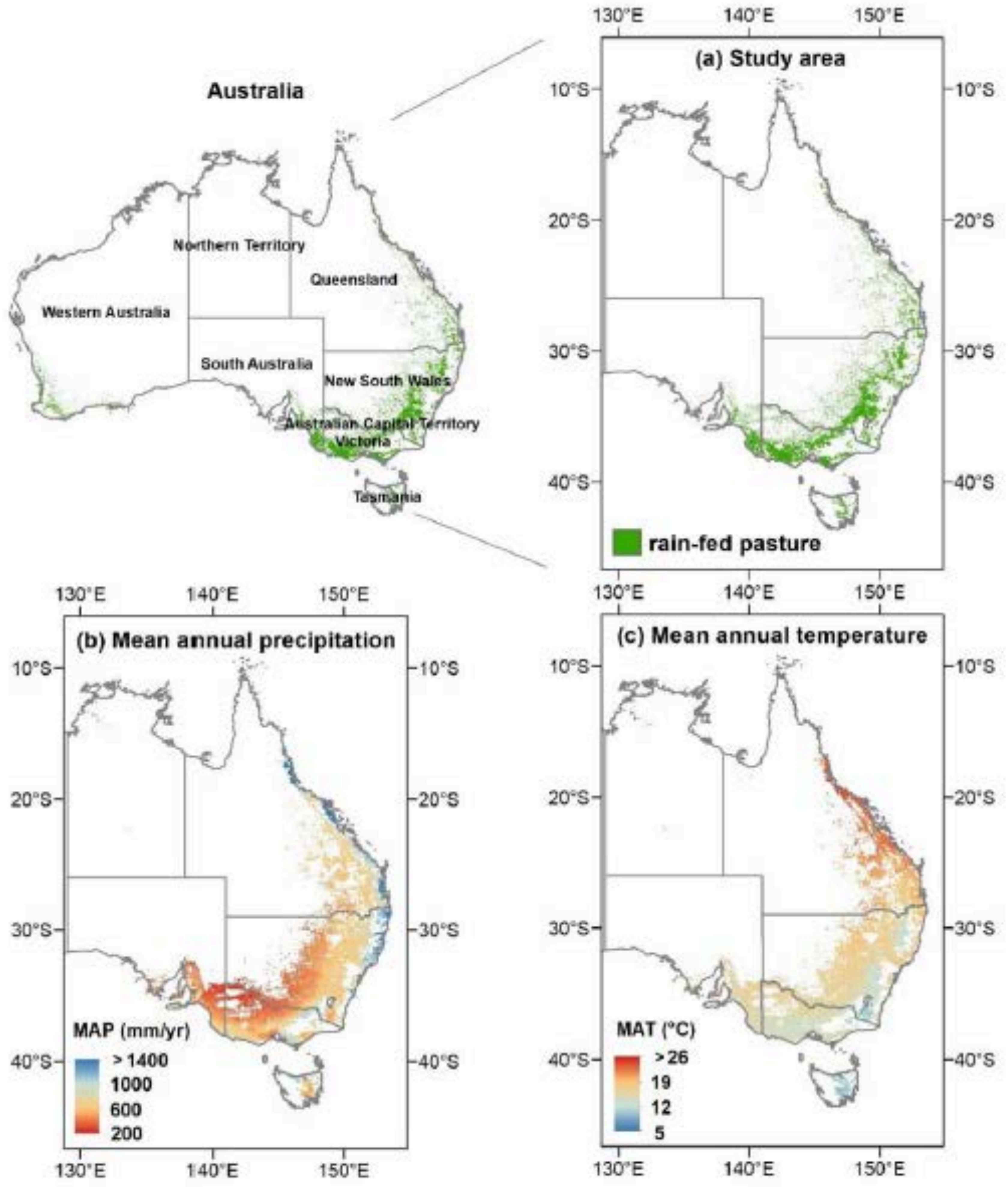


Figure 1. Study area and mean climatology. (a) Grass map in 2015 according to the National Dynamic Land Cover Dataset; (b) Mean annual precipitation (MAP) during 2003-2017, (c) Mean annual temperature (MAT) during 2003-2017.

Satellite-observed shifts in C_3/C_4 abundance in Australian grasslands are associated

Peak of growing season with latitude

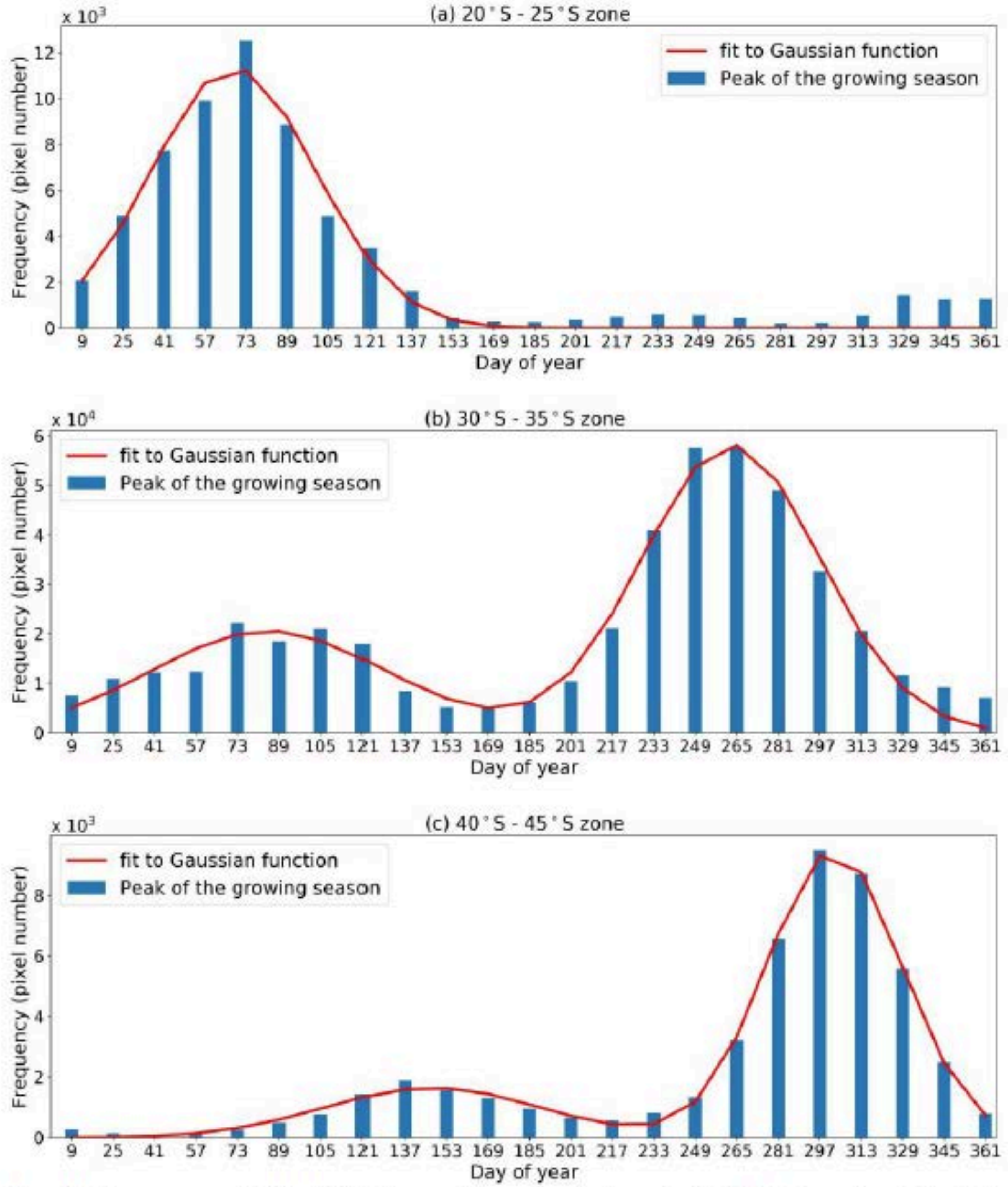
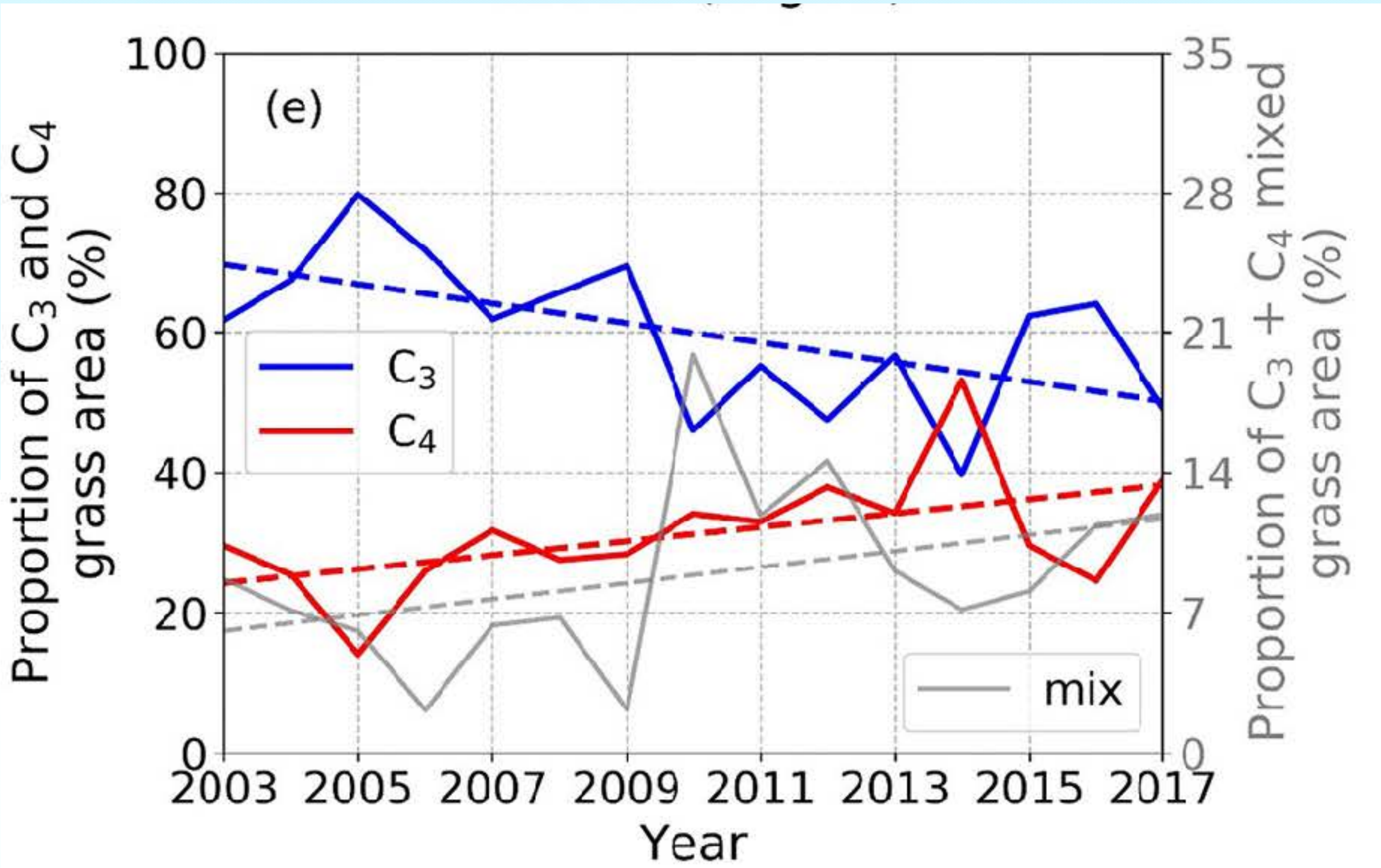


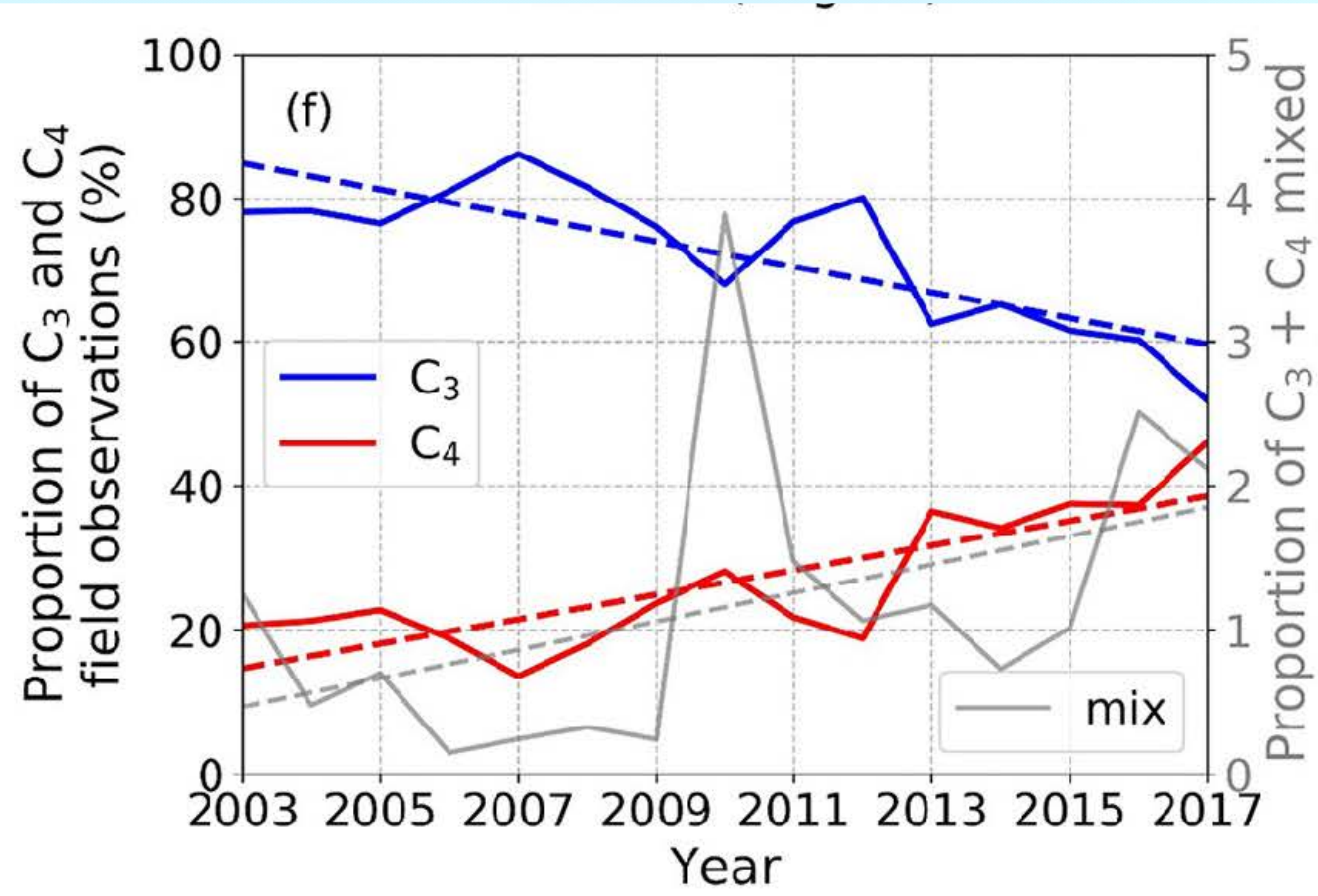
Figure A2. 15-year average (2003 to 2017) histogram of the peak productive period, at 16-day temporal resolution, inferred by satellite-derived grass phenology for 500 m rain-fed pasture pixels in three latitudinal zones (20 °S-25 °S, 30 °S-35 °S, and 40 °S-45 °S) from north to south in our study area.

Xie et al., RSE 2022

Trends in C3 and C4 grasses

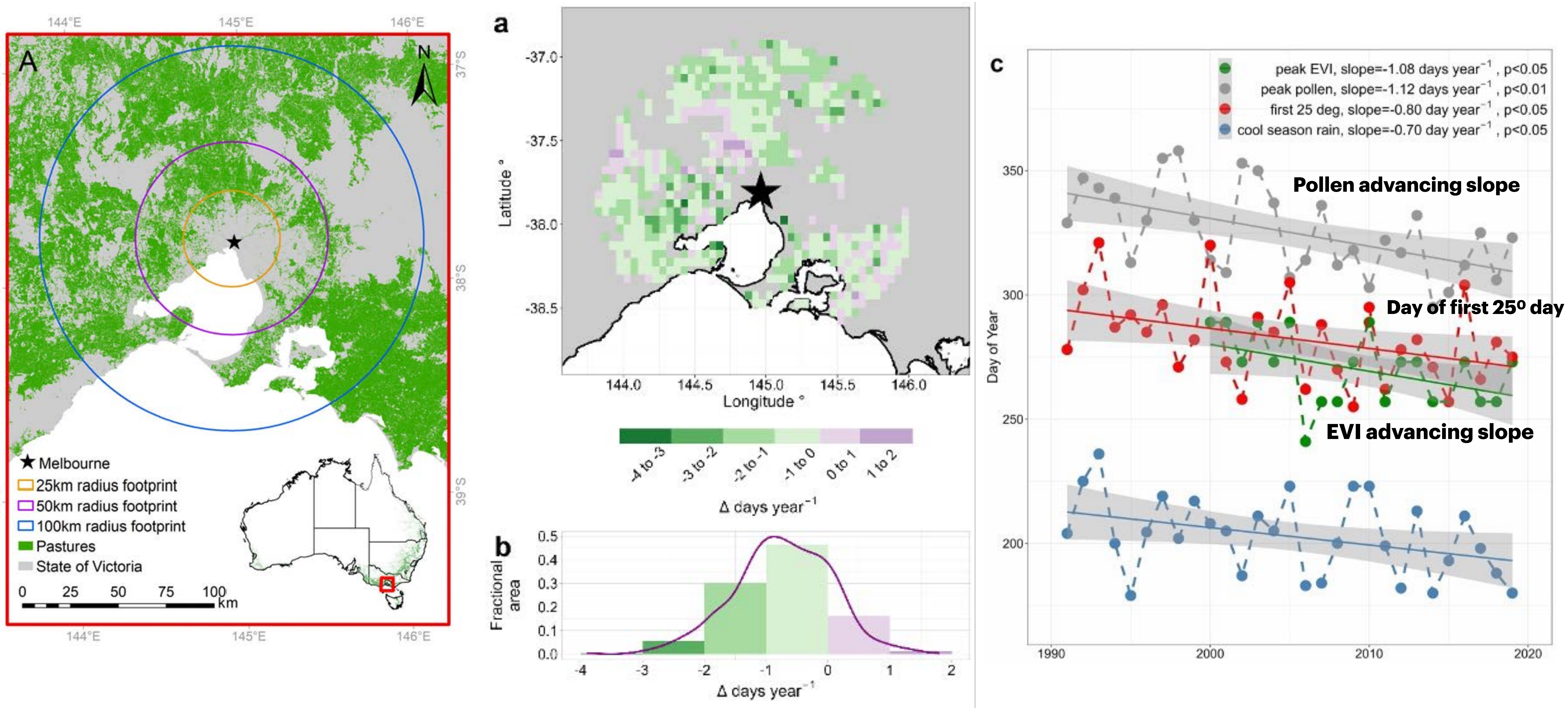


MODIS-derived from Phenology



Citizen science (Atlas of Living Australia)

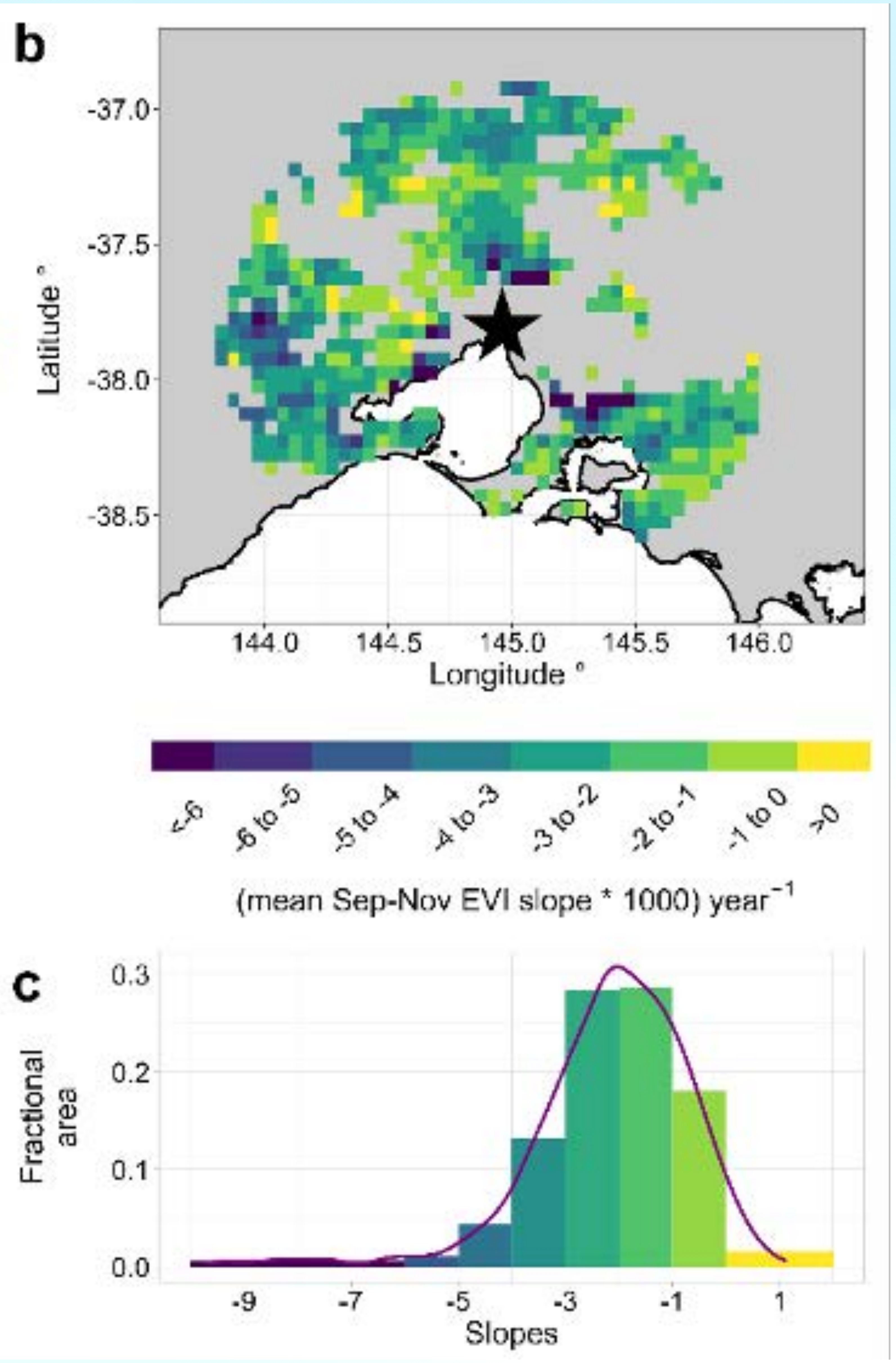
Xie et al., RSE 2022



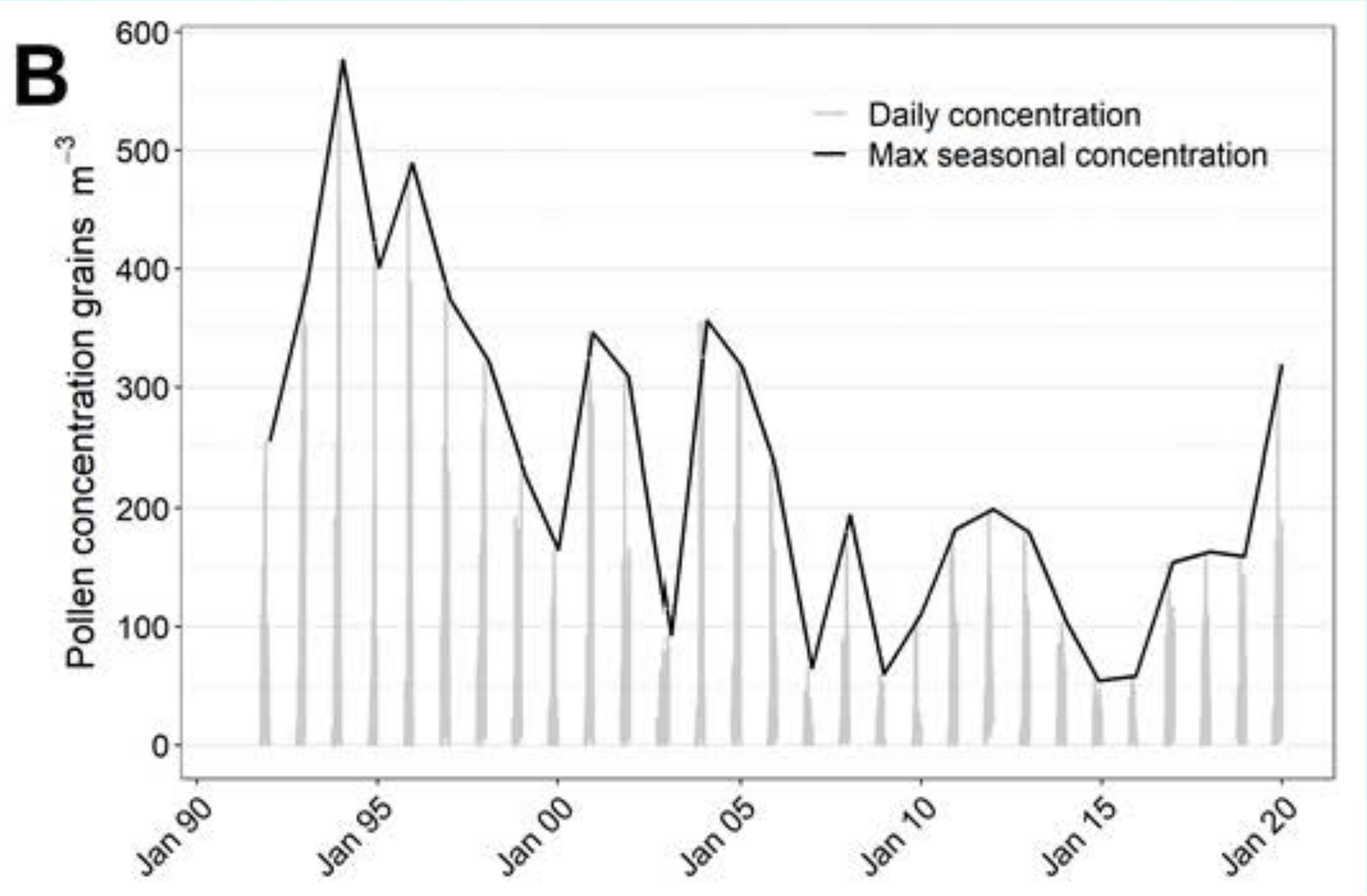
Nguyen, H et al., (In Prep)

Nguyen, H et al., (In Prep)

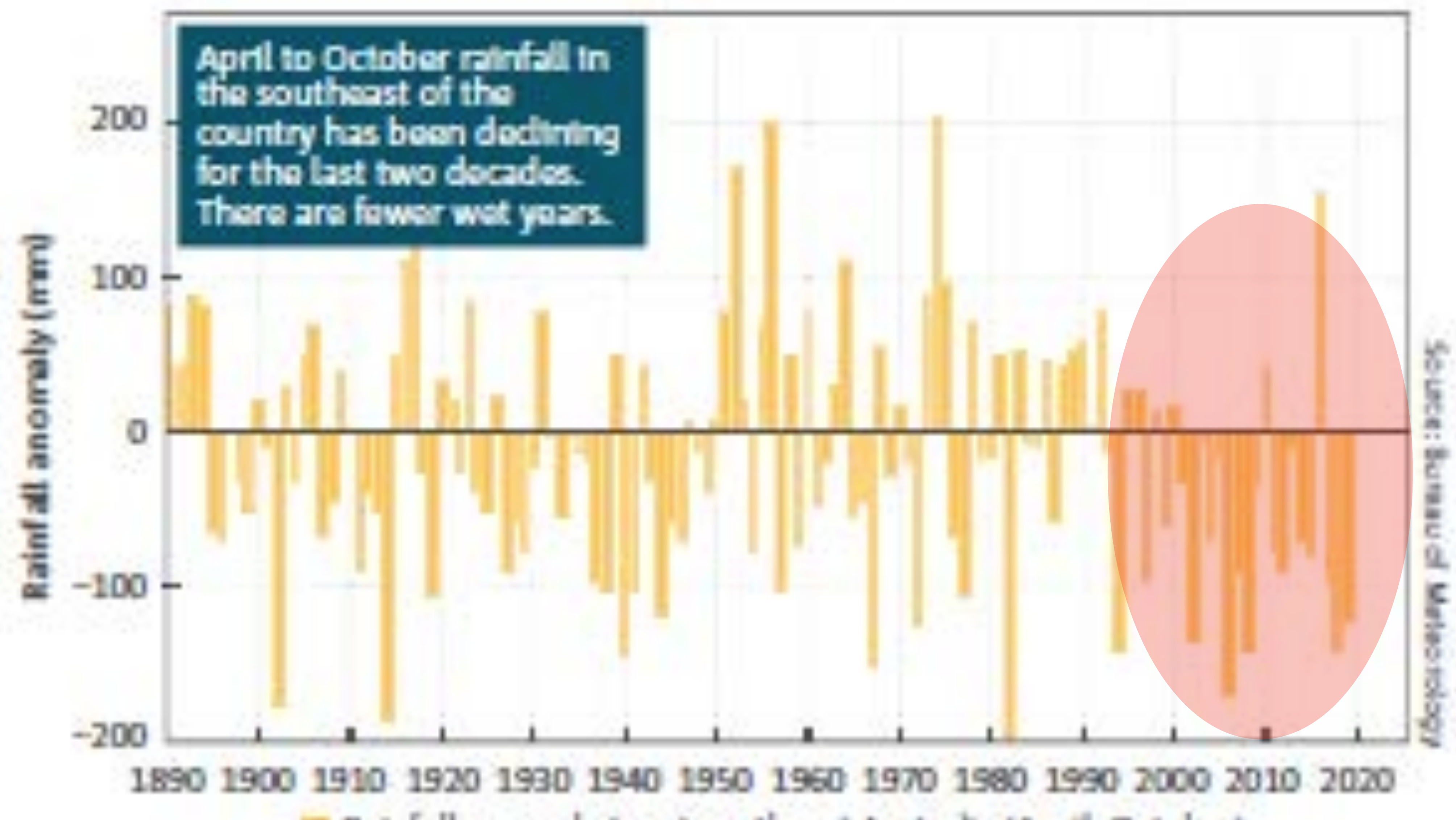
Both the seasonal pollen index (SPI) and integrated EVI values are declining



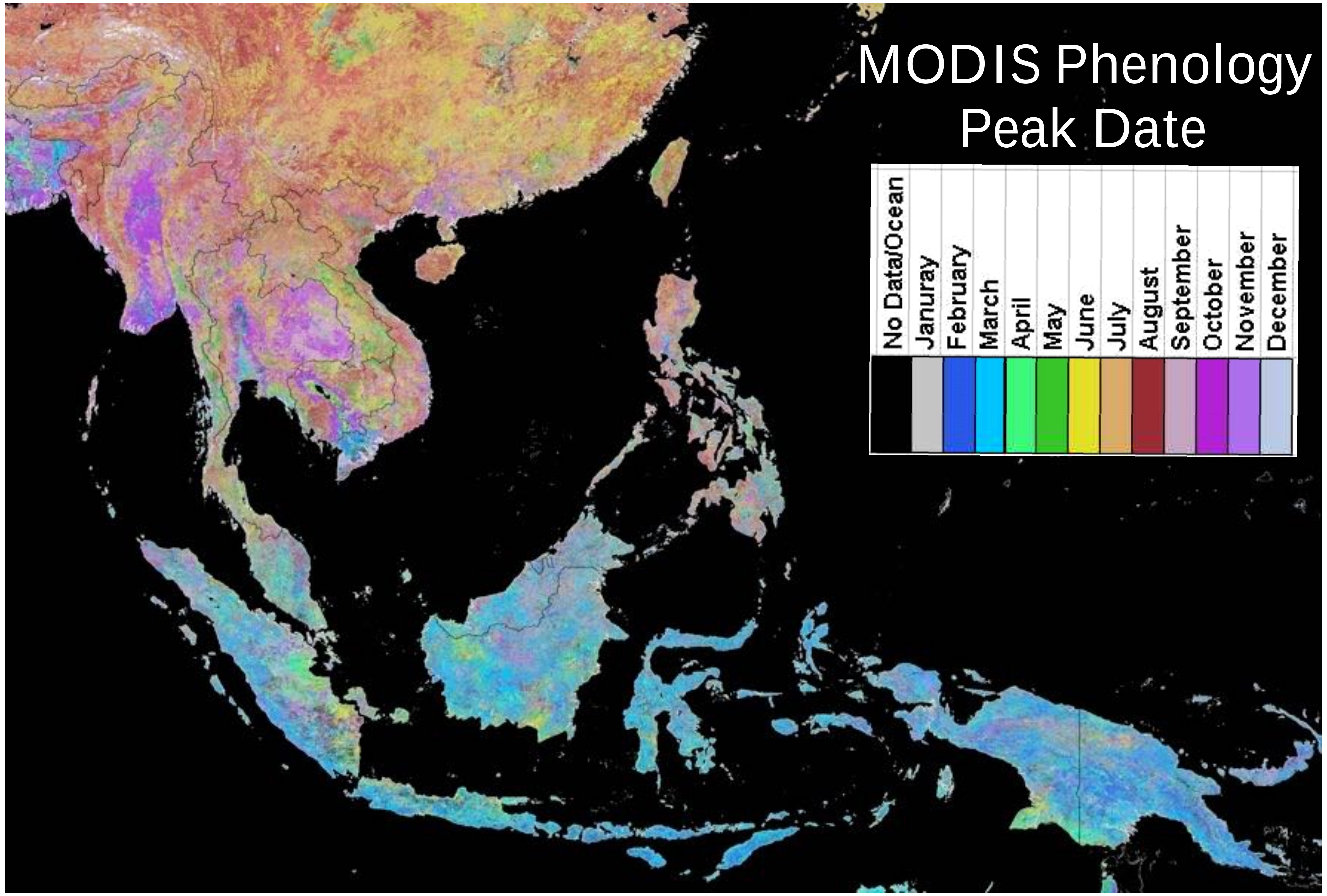
Nguyen, H et al., (In Prep)

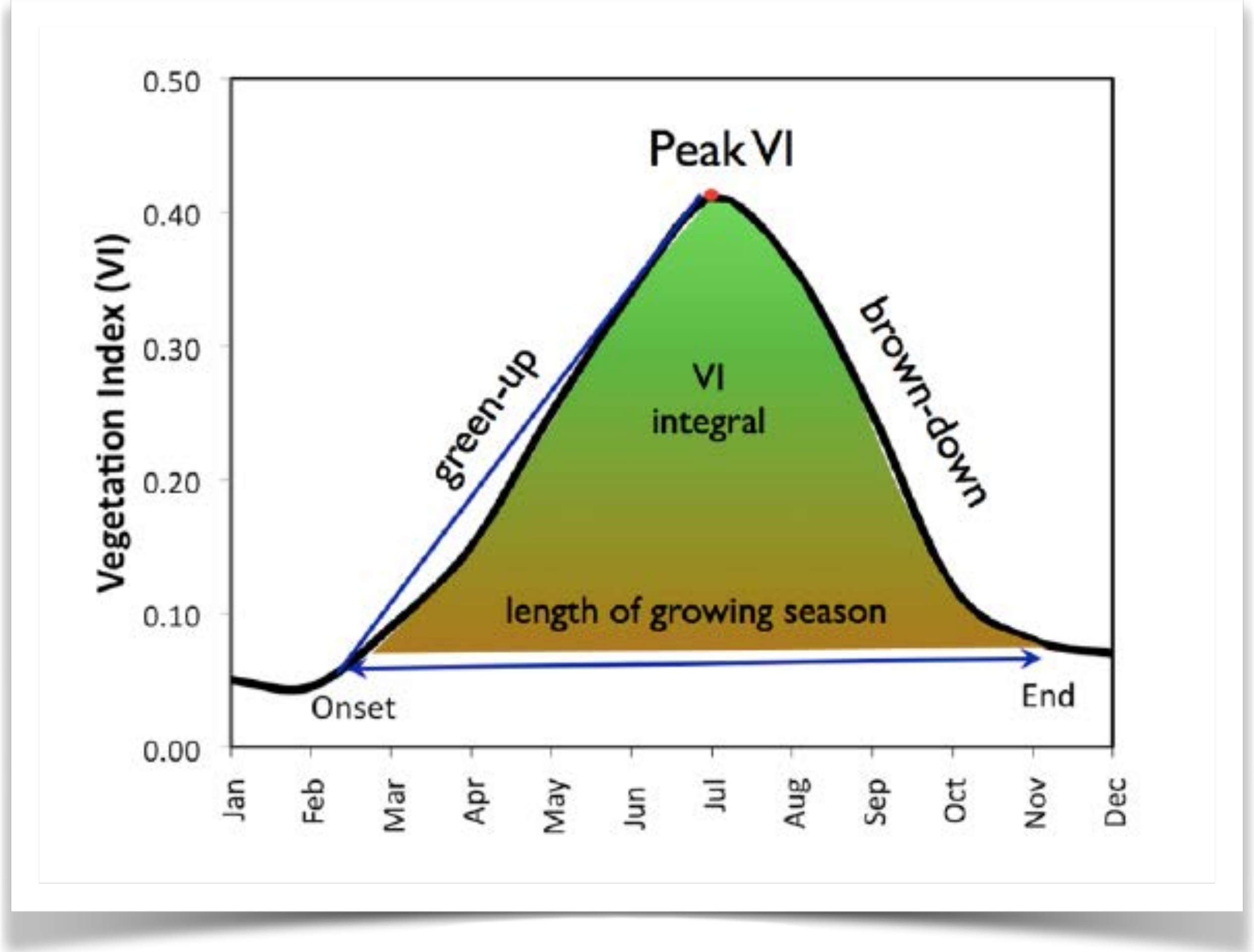


Cool season rainfall has been declining for past 30 years (Bureau of Meteorology)

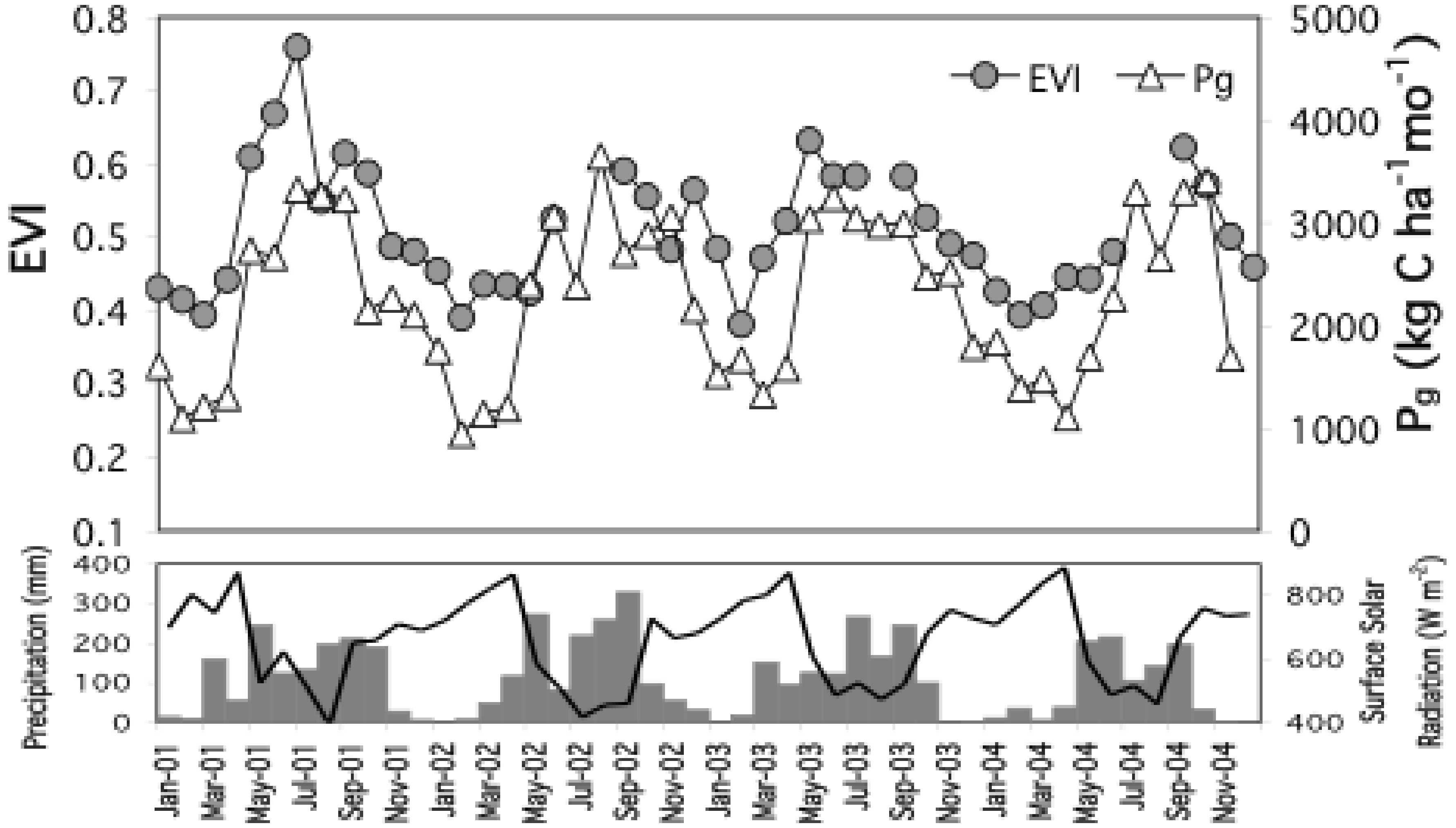


Phenology of SE Asia





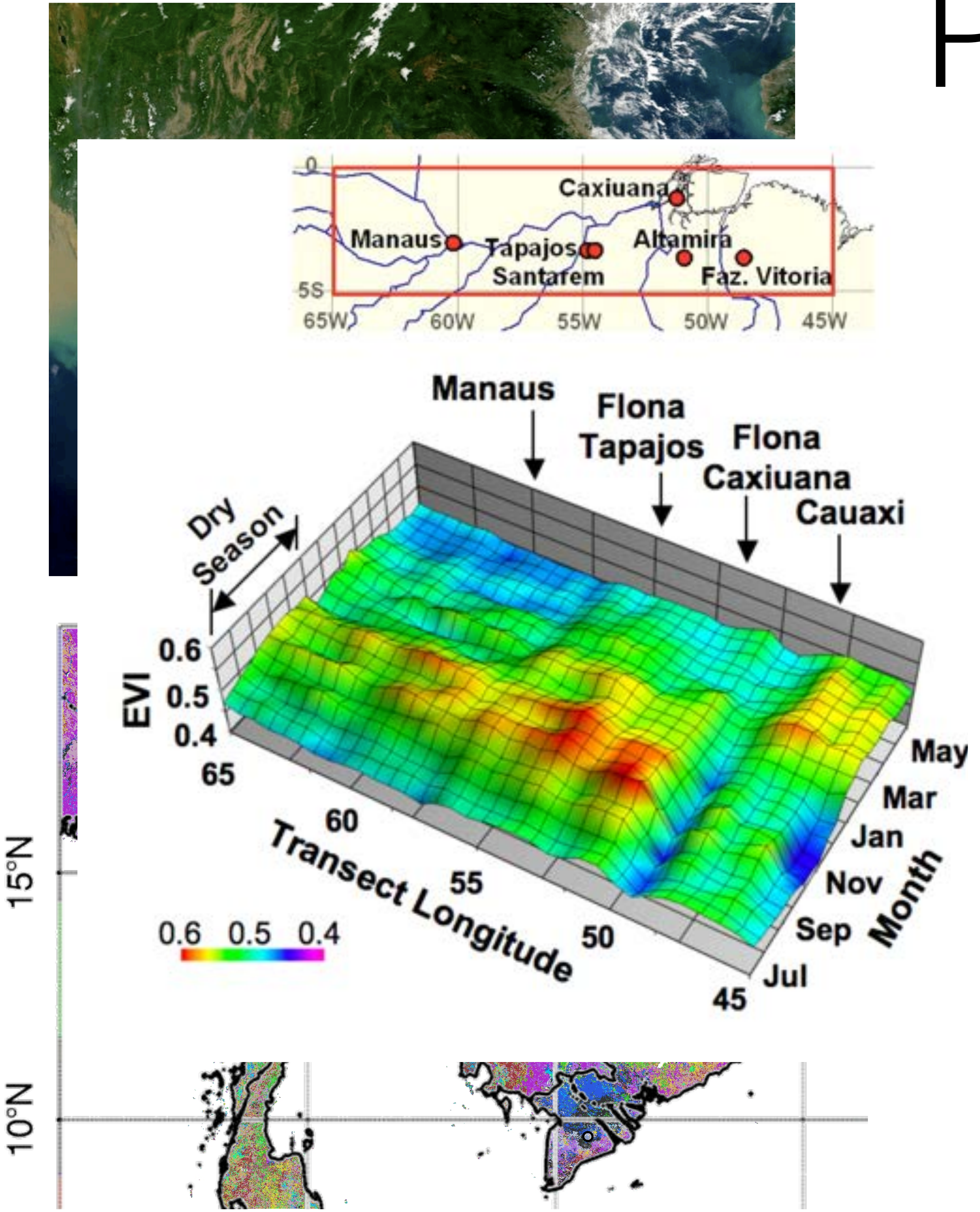
Validate with flux tower



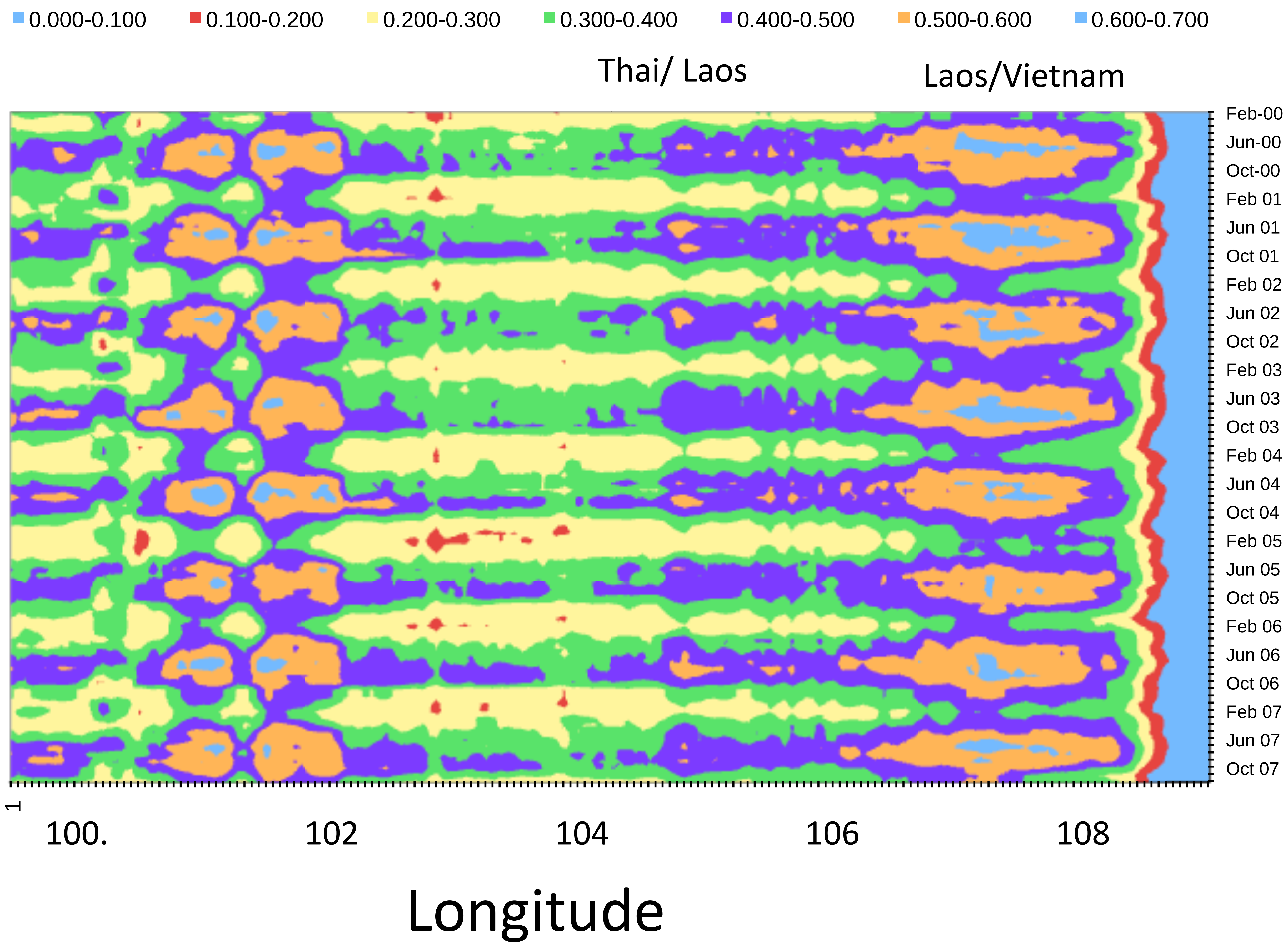
Huete et al., AFM (2008)

In Monsoon Asia there are more forest disturbance regimes - impacting vegetation seasonality

Phenology of SE Asia



East-West Economic Corridor



This figure shows interannual pulses of green-up and brown-down along this corridor bisecting biodiversity areas, national parks, and economic development areas.

Huete et al., (In Prep)

Multi-institution TERN project

"Developing best-practice Himawari data products for enhanced sub-daily monitoring and climate impact studies of Australia's ecosystems"

Tim R. McVicar (CSIRO)

Alfredo R. Huete (University of Technology Sydney)

Luigi J. Renzullo (Bureau of Meteorology)

Thomas G. Van Niel, Yi Qin, Qiaoyun Xie, Ngoc Tran, Ankur Srivastava, Abhirup Dikshit, Siyuan Tian, Yi Yu, Jamie Vleeshouwer and Ashley Sommer

tern

Ecosystem Research Infrastructure

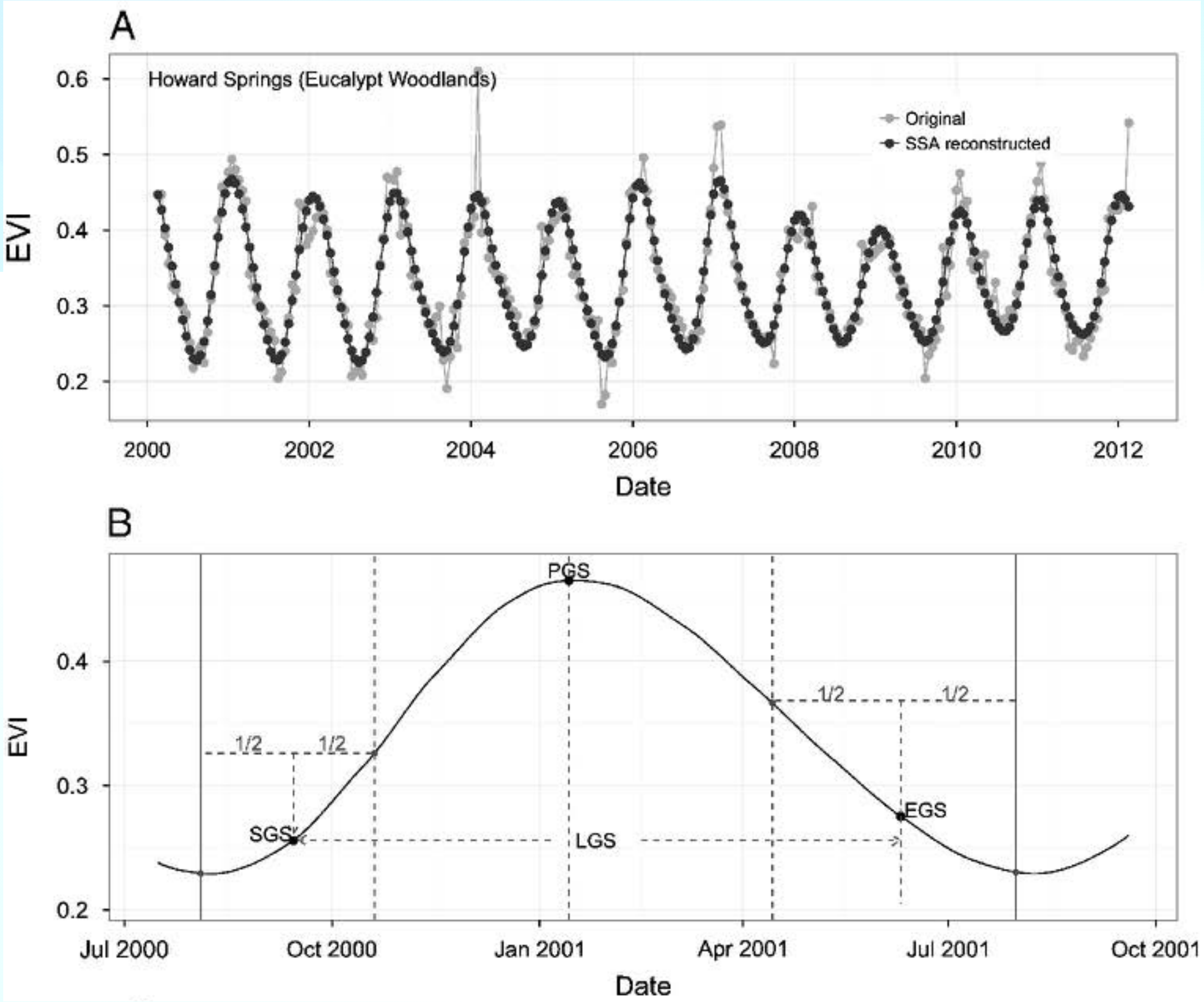
- Produce Level 1 products of: (a) reflectance; (b) albedo; (c) surface solar irradiance (total partitioned into the direct and diffuse components); and (d) land surface temperature.

- These Level 1 products are then linked with biophysical models / analytical frameworks to monitor Level 2 sub-daily / daily processes including:

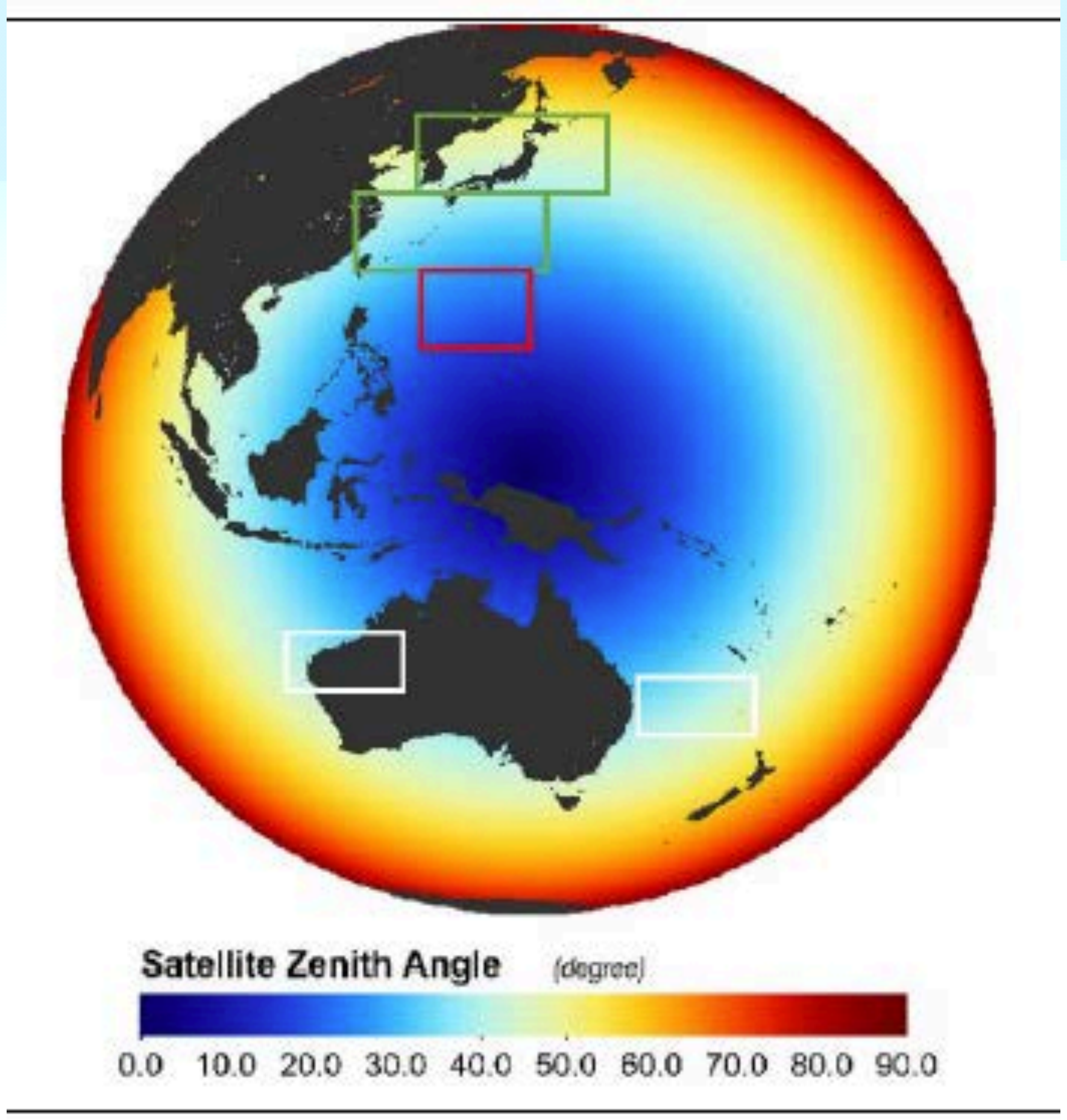
  - **Gross Primary Productivity (GPP);**
  - **Actual evapotranspiration (AET);**
  - **Ecosystem stress, Light Use Efficiency (LUE) and Water Use Efficiency (WUE);**
  - **Photosynthetic capacity (Pc); and**
  - **Phenological processes that initiate and define all of the above.**

Choosing a Himawari dataset for Phenology

- Phenology is about the timing of vegetation growth life cycles
- The Advance Himawari Imaging (AHI) Sensor generates 10 minute repetitive imagery, hence can improve upon land surface phenology (LSP)

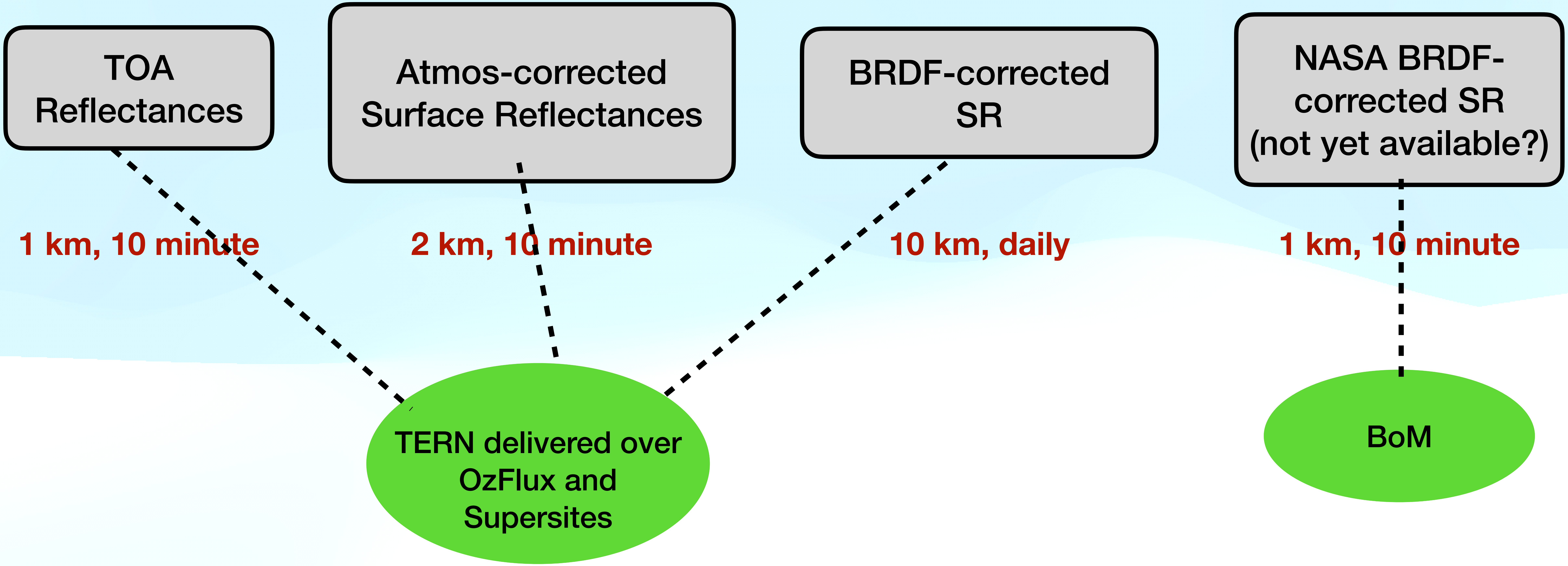


Ma, X. et al., (2013) RSE



Fearns, TERN Himawari Technical Report for AusCover (2017)

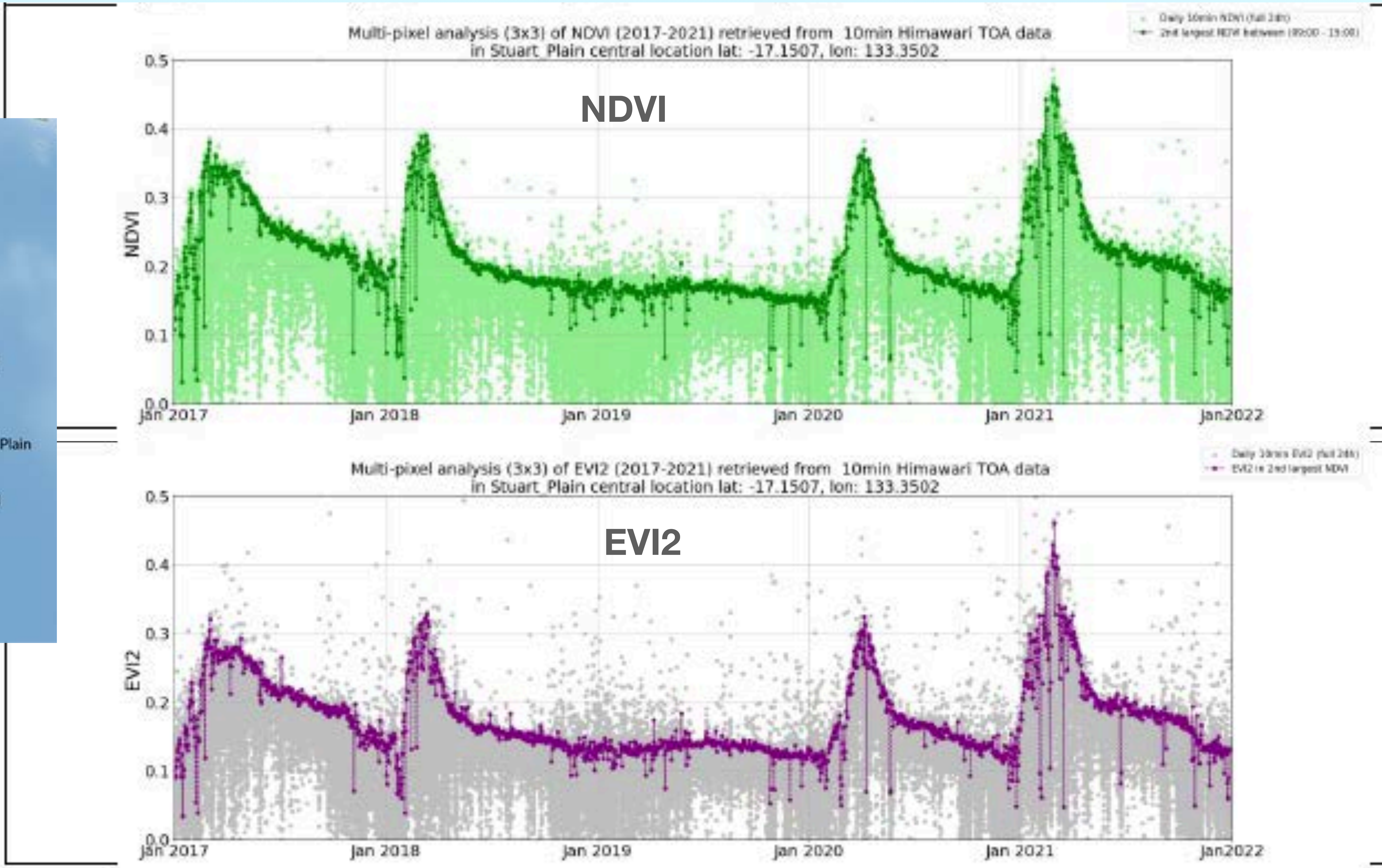
Himawari AHI Datasets (Phenology)



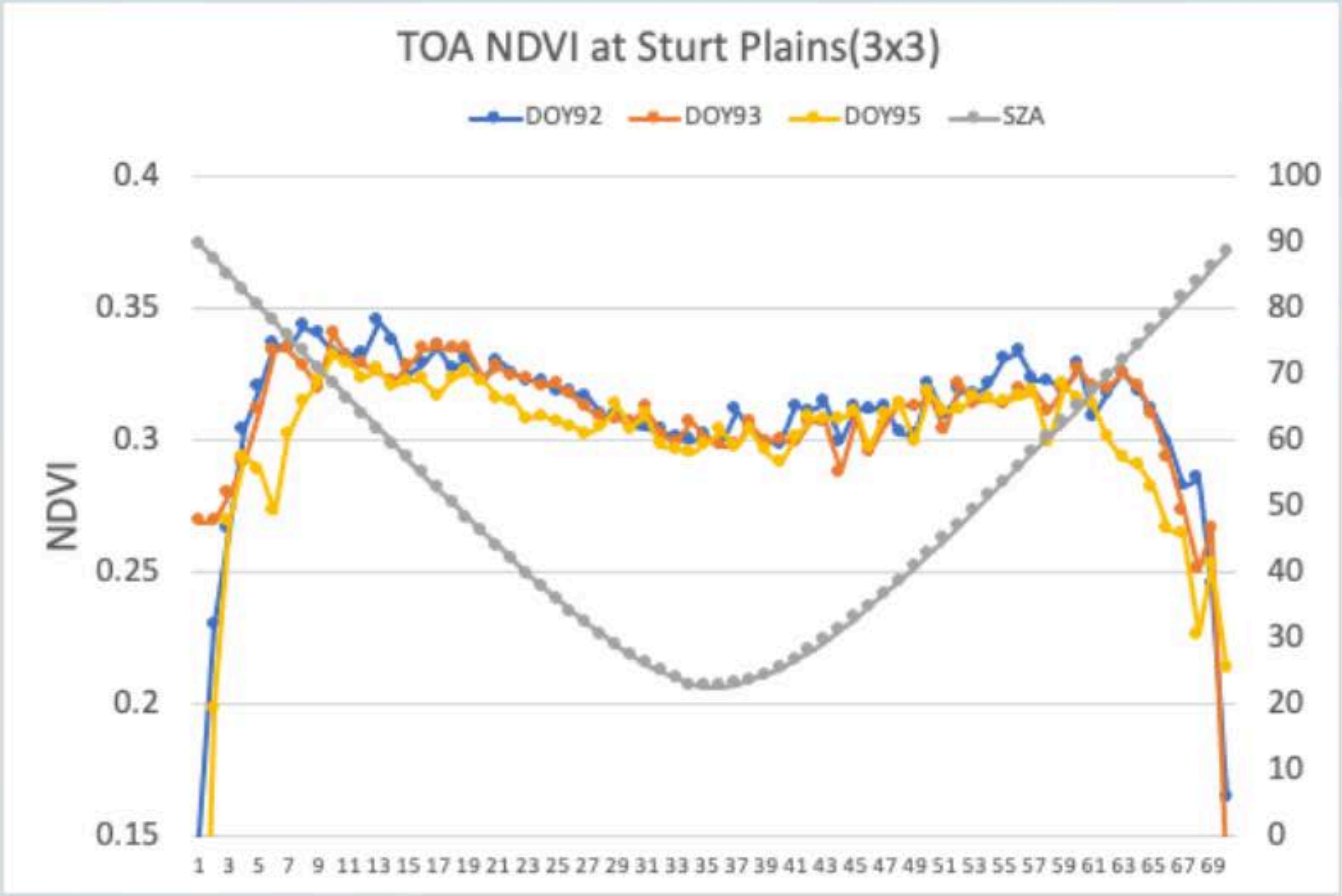
Inverse relationship between data quality and spatial-temporal resolutions

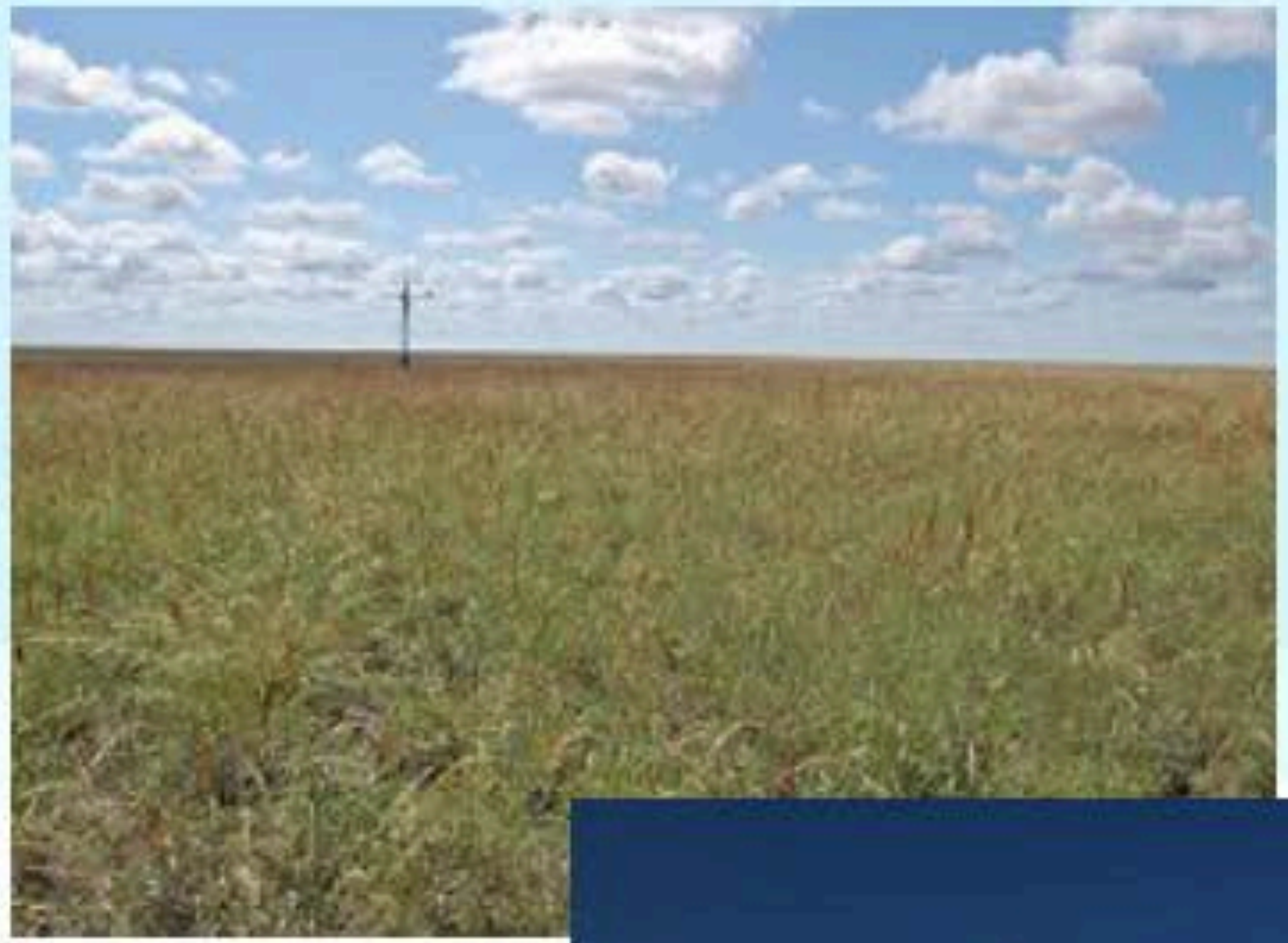
Study Site

Himawari AHI TOA - VIs at Sturt Plains (2017-2022)

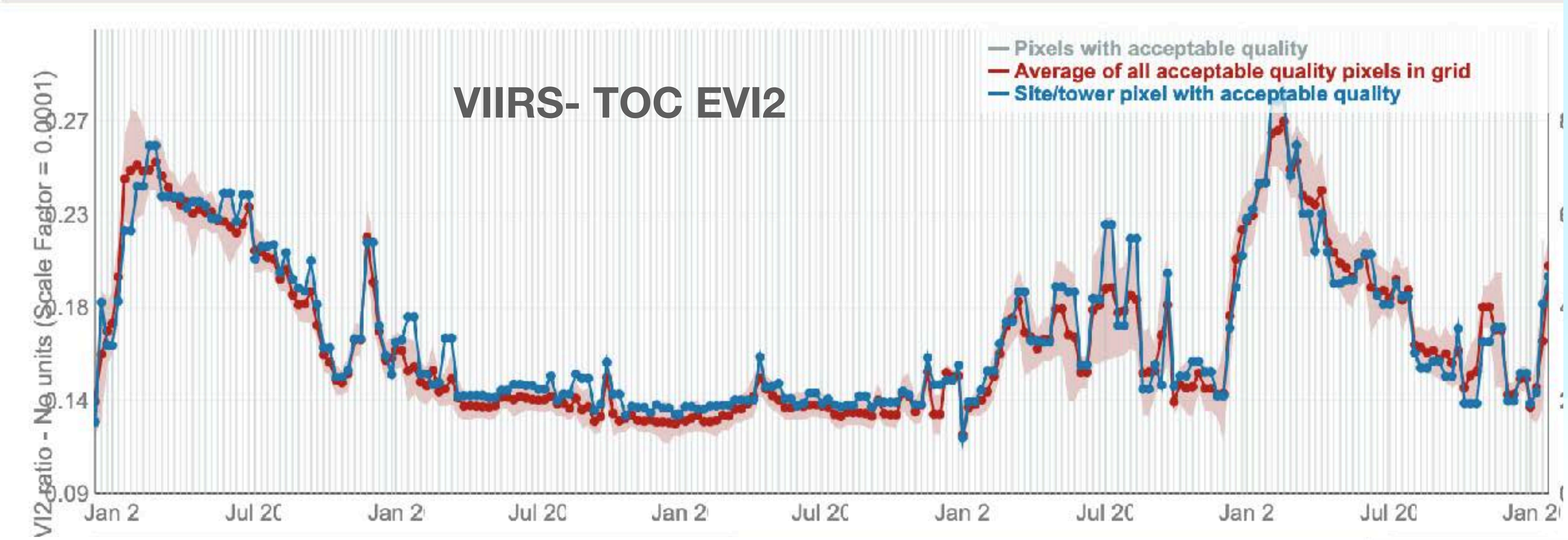


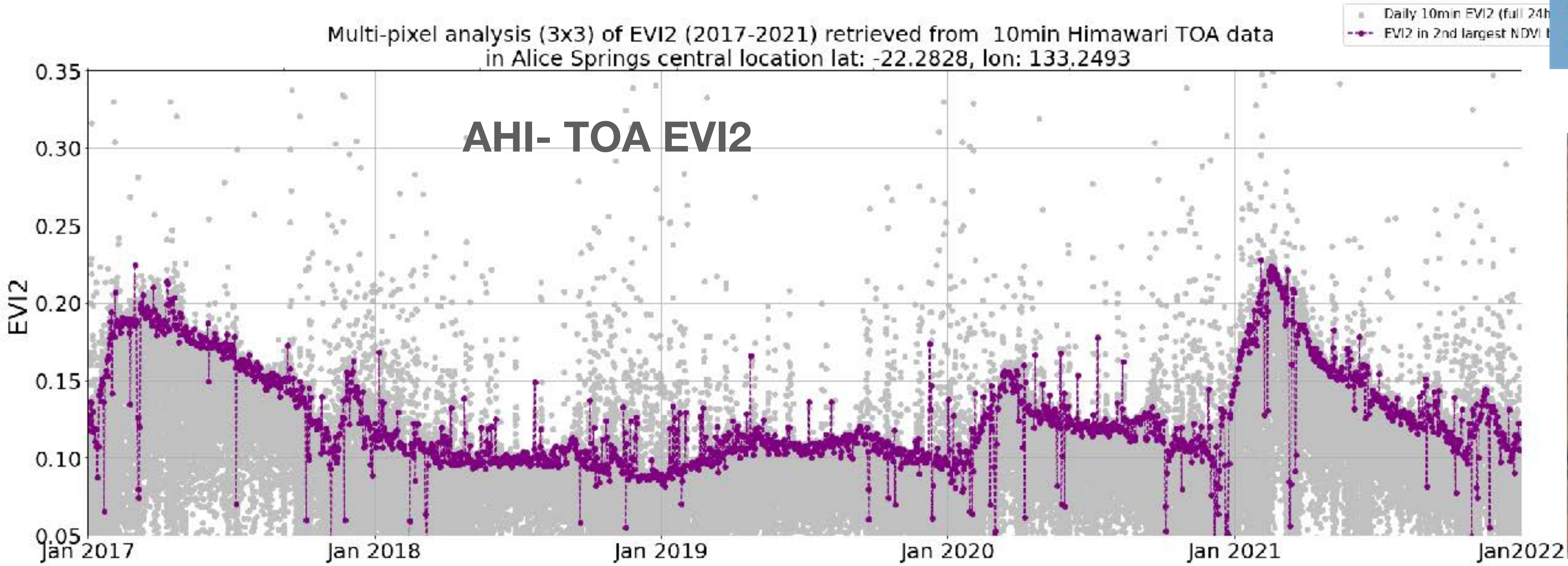
Diurnal NDVI at peak greenness

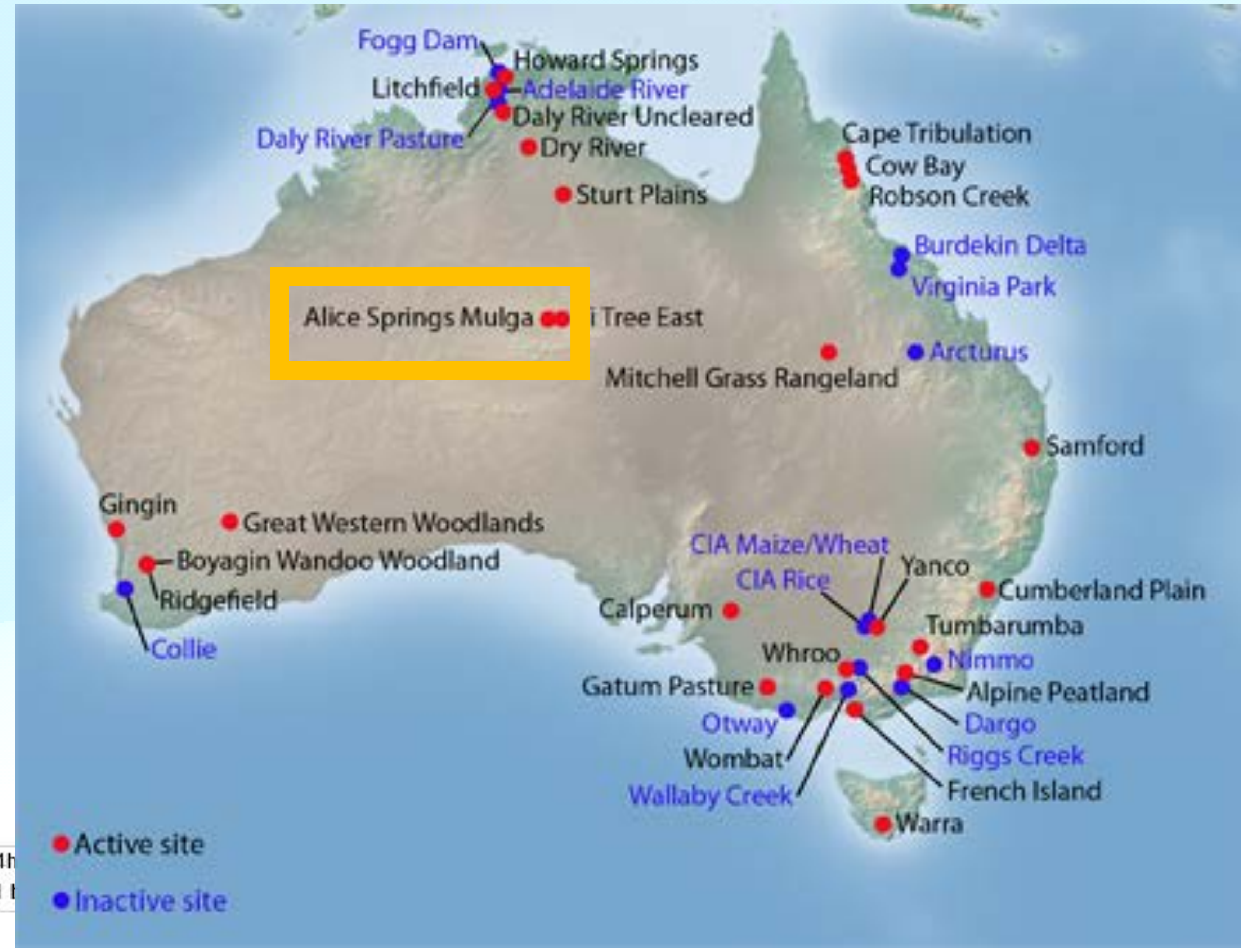




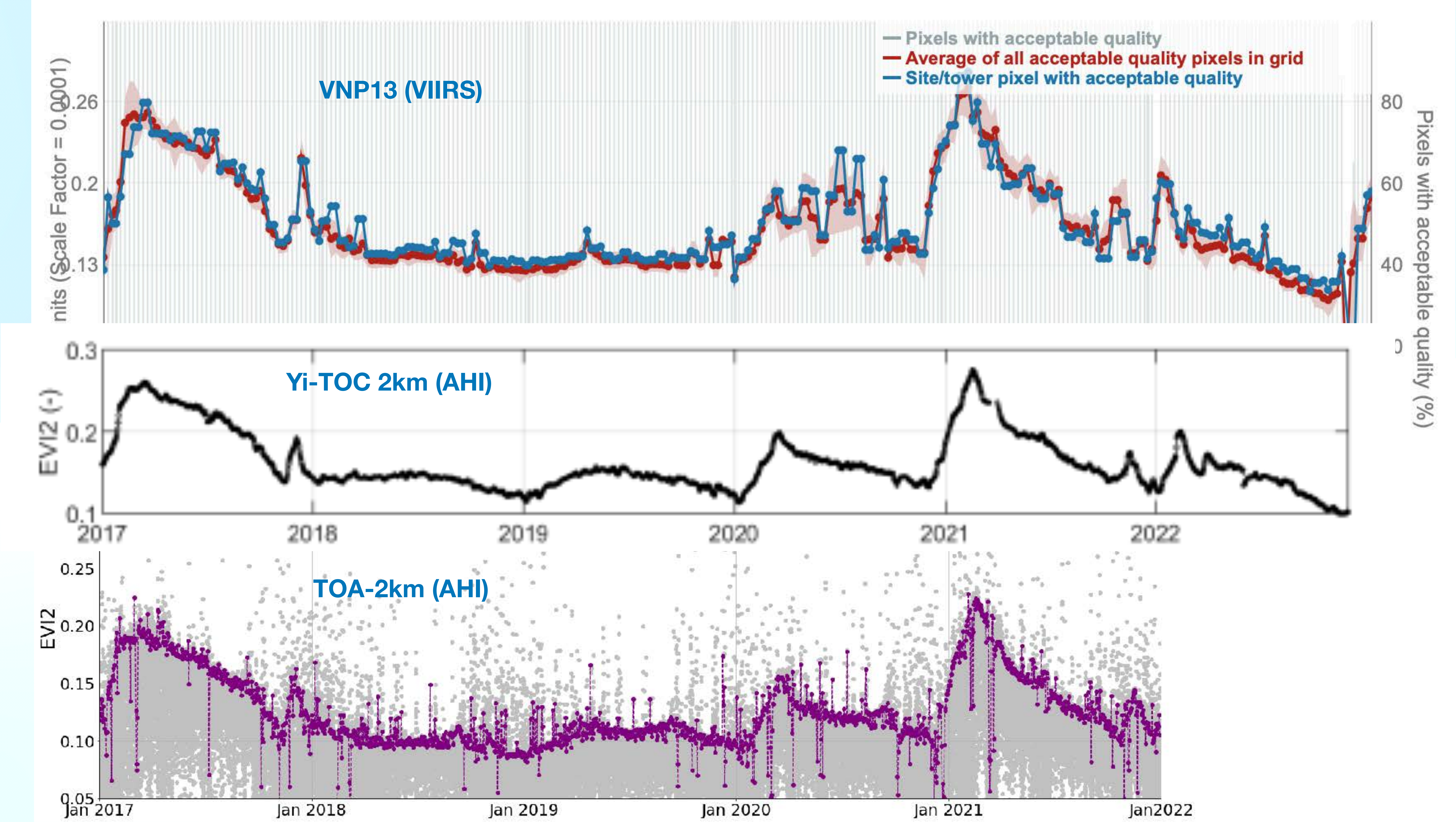
AHI-(TOA) EVI2 vs VIIRS (TOC) EVI2 at Alice Springs



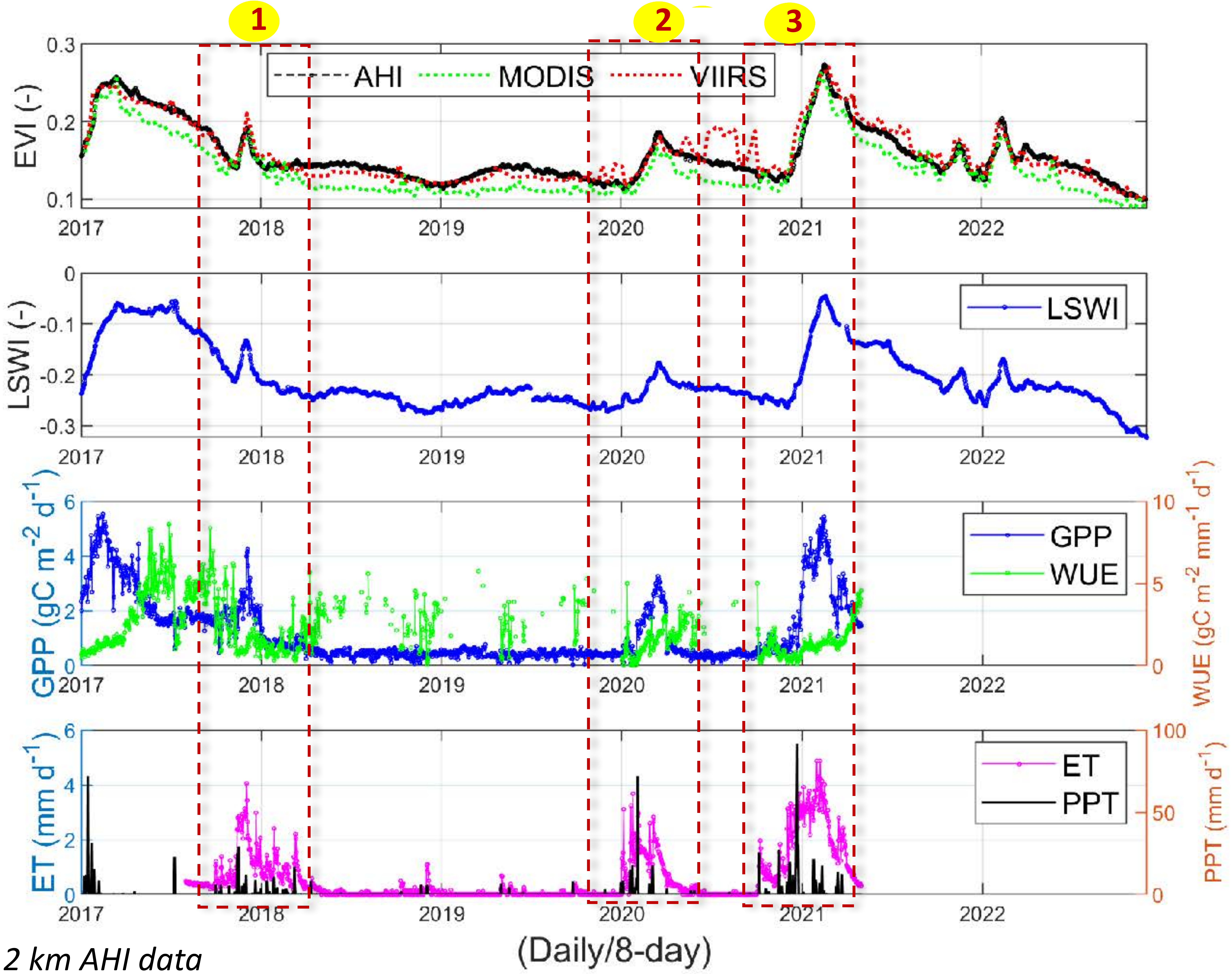




Comparison of 3 products at Alice Springs



Temporal variations of RS data (EVI2 from AHI, VIIRS, and MODIS) and station data (GPP, ET, and WUE) from flux tower



2 km AHI data

- AHI EVI2 matches MODIS well, while VIIRS diverges somewhat
- LSWI (plant moisture index) has a similar pattern to that of EVI2
- Seasonal dynamics of EVI2 matches well with GPP, capturing all plant responses to wet periods
- ET shows the earliest response to wet pulses, relative to GPP and VI
- Multiple rain events in early 2018 are captured in Himawari-greenness measures

Srivastava et al (in preparation)

CONCLUSIONS

- Continue working with geostationary community for development and application of high frequency (10') satellite data
- Work with Aircas (Drs. Jing Li & Qinhuo Liu) in identification and characterisation of ecologic hotspots
- Work on phenology - biodiversity interactions in drylands ecosystems and their assessment with satellite data.
- Incorporate multi-resolution fusion and machine learning techniques