# EO of phenology for land surface modellers and ecologists - From field radiometry to MODIS time-series of NDVI.

**France Gerard**, Centre for Ecology and Hydrology, UK;

- **Charles George,** CEH, UK
- **Cecilia Chavana-Bryant,** Oxford Univ., UK
- **Graham Weedon,** Met. Office, UK;
- **Garry Hayman,** CEH, UK
- **Yadvinder Malhi,** Oxford Univ., UK
- **Andrew Bradley,** Imperial college,UK

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

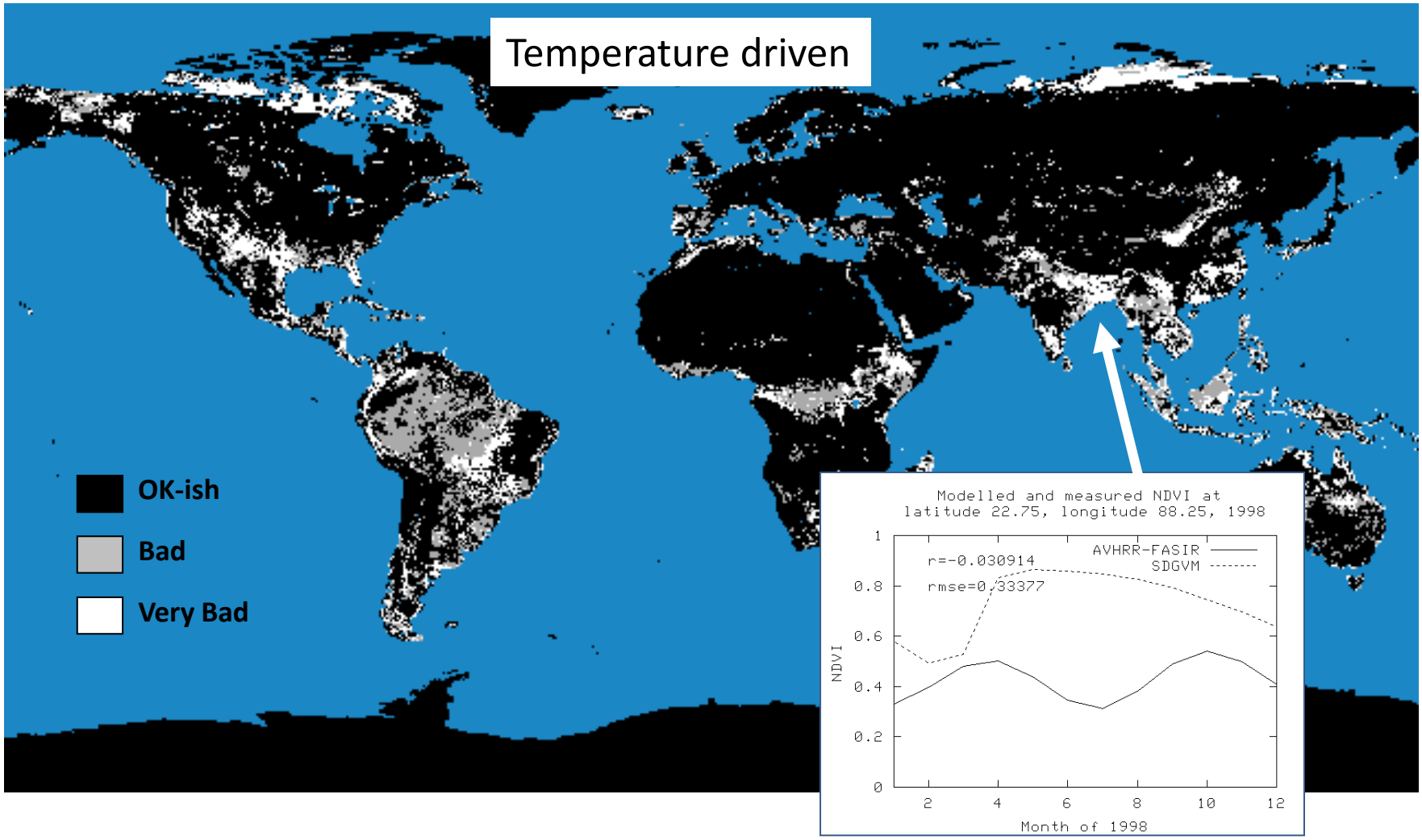
# My 20 minute story today

- Phenology and land surface modelling

Dynamic Global Vegetation Model part of the land surface models

- Phenology with MODIS style data
- Phenology with in situ radiometry

# Phenology representation in models -10 yrs ago




Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Old slide from M.Disney, P.Lewis and S.Quegan
(University College London & Sheffield Univ.)

# Phenology in models – current efforts

**JULES:** at least 3 different schemes being developed; one involves the introduction of a drought deciduous Plant functional type.

**ORCHIDEE:** a new leaf litter fall dynamics scheme for tropical plant functional type. It results in a higher leaf turnover in periods of high productivity. Other activities?

**LPJ** and other models: ask the audience….

# Modellers: Tell us about phenology !

**Question in 2005 – in tropical America, what is driving Phenology, radiation or precipitation ?**

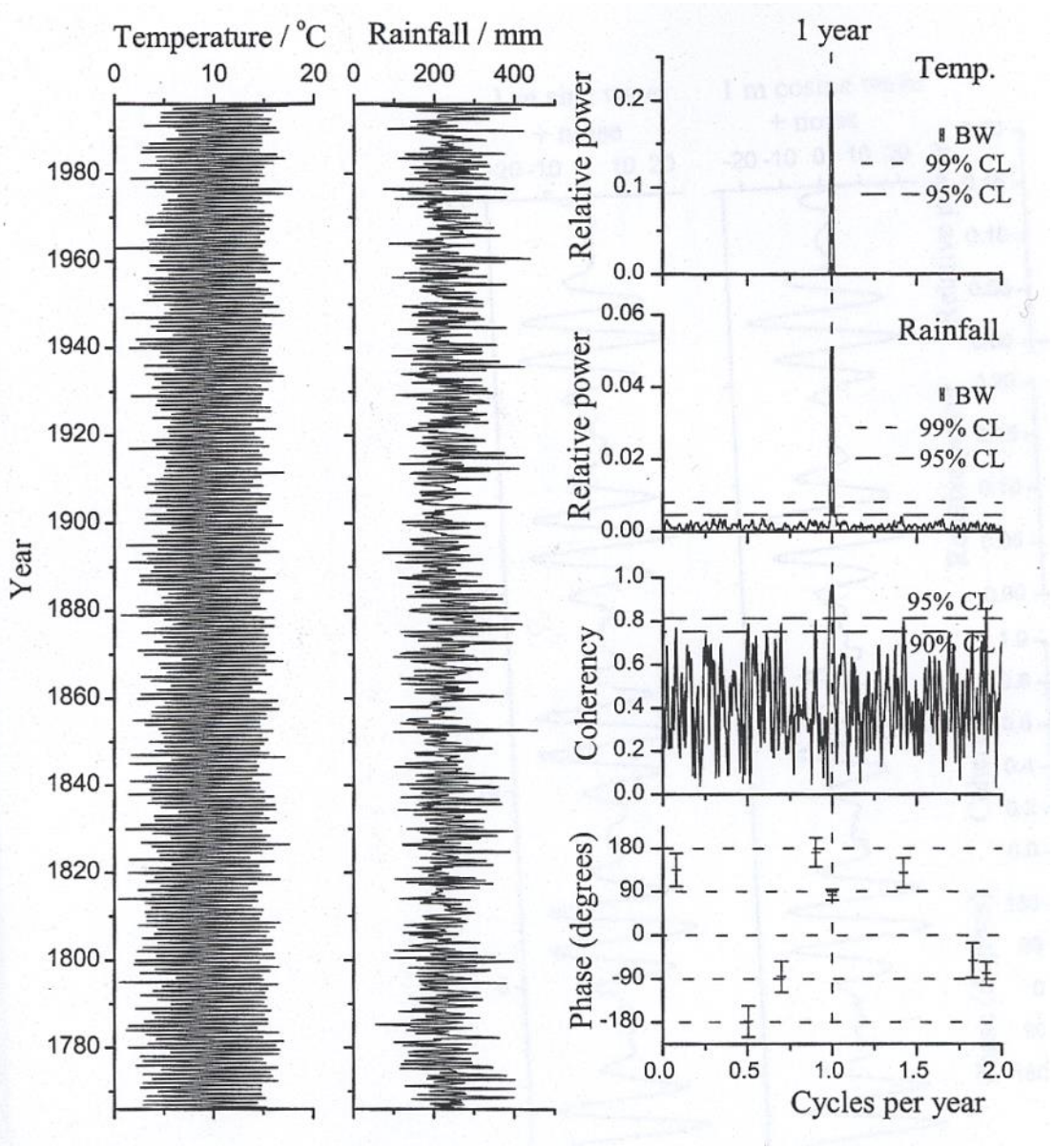
*Global Change Biology, 17: 2245–2260, June 2011; doi: 10.1111/j.1365-2486.2011.02405.x*

**Question in 2012 – tropical and subtropical America, where are the forests evergreen, deciduous ?**

*In Prep.*

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# Approach: Fourier based analysis




## Spectral Analysis

To detect a periodic or quasi-periodic components in a time series

## Coherency Analysis

Compare pairs of time series

Coherency = measure of similarity

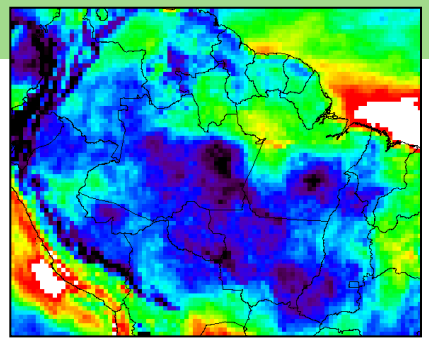
Difference in phase

Weedon G (2003) Time-Series Analysis and Cyclostratigraphy. Cambridge University Press

## Leaf phenology

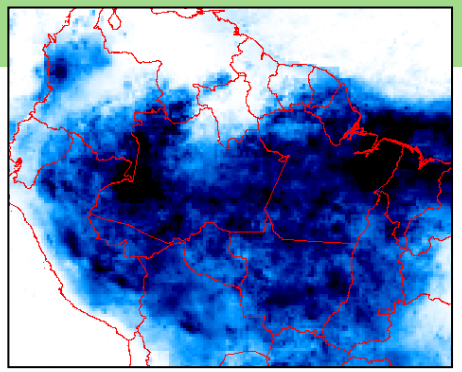
EVI & NDVI- MODIS
1km, monthly,
2000 – 2006

## Radiation



CPTEC GL-1.2 physical model
0.4° x 0.4°, monthly
2000 – 2006

## Precipitation

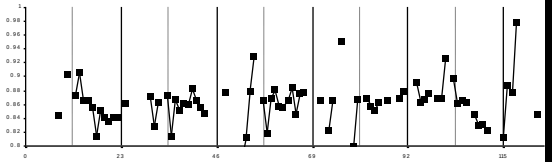


TRMM
0.25° x 0.25°, monthly
2000-2006

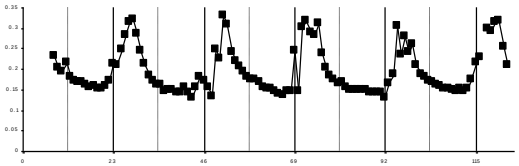
~ 7 yr time period was determined by the CPTEC radiation and MODIS data
For coherency analysis, data were re-sampled to match CPTEC radiation data:0.4° x 0.4°,

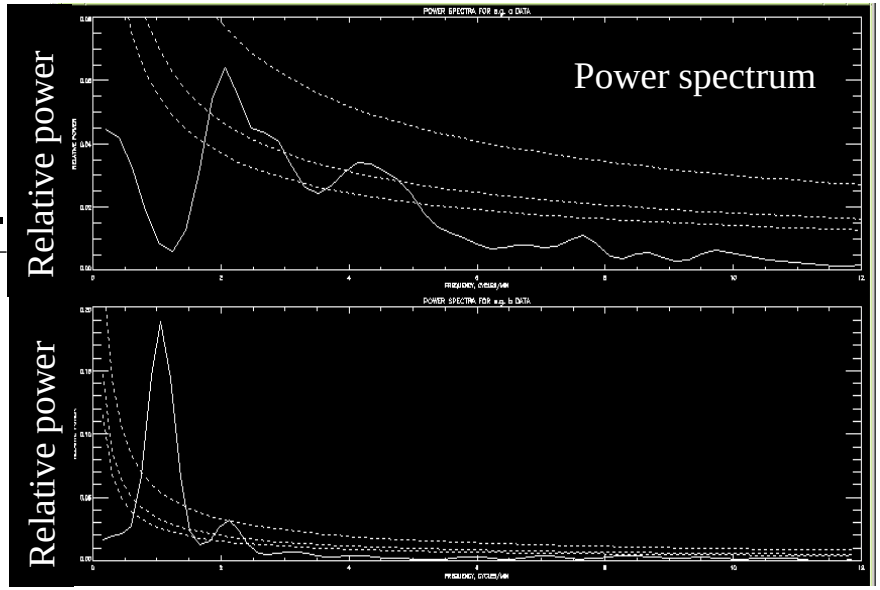
MODIS VI time series (~ 5 yrs)

Humid forest

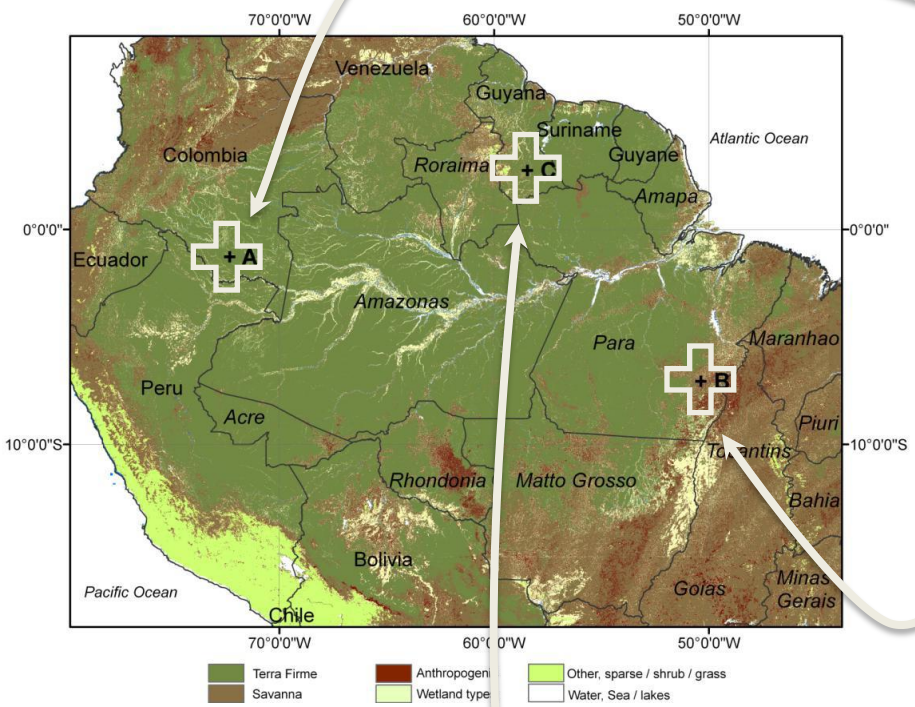


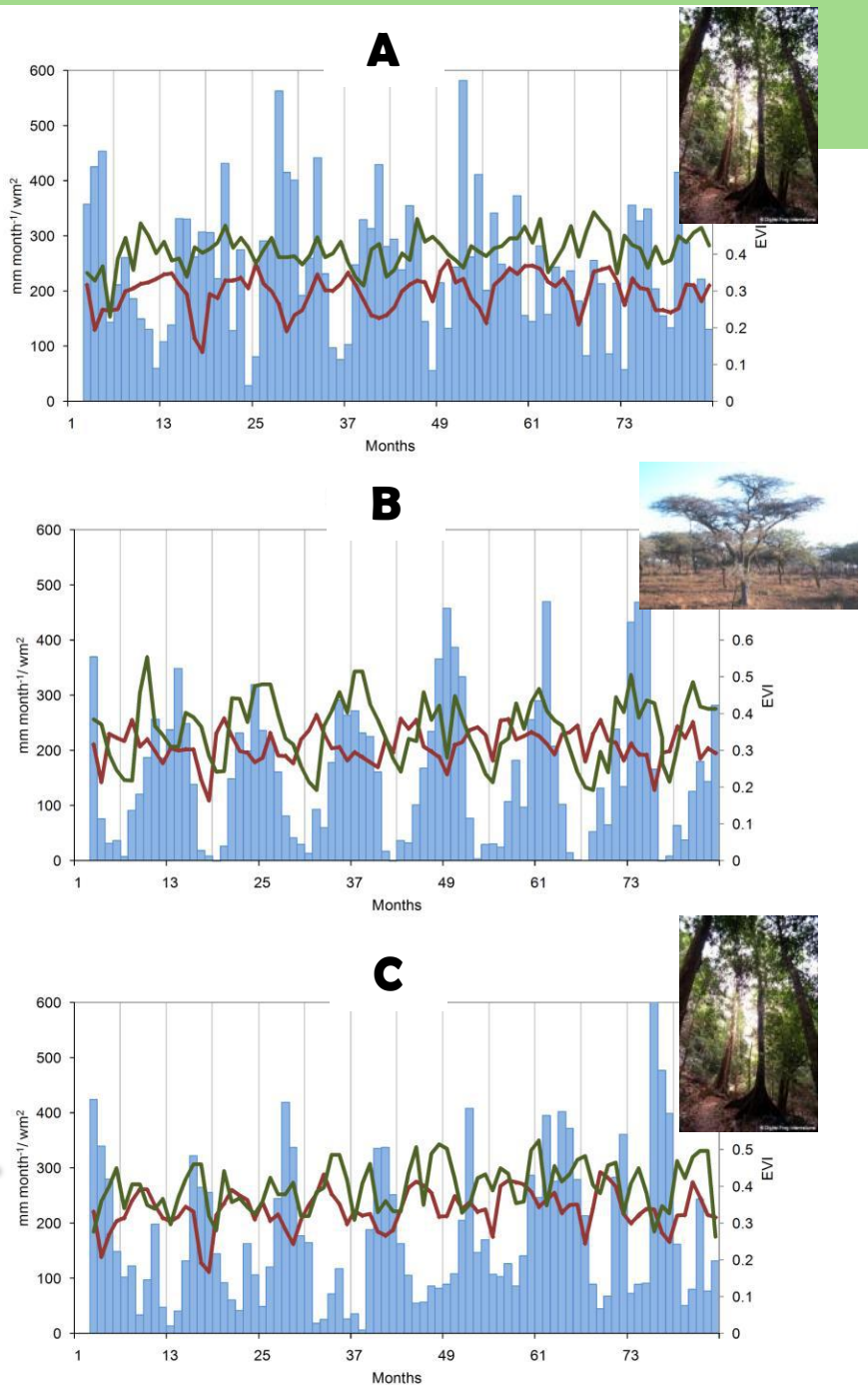
Grassland





# Example time-series



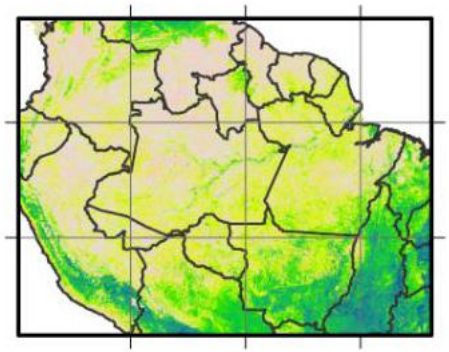

Blue: precipitation
Red: radiation
Green: EVI

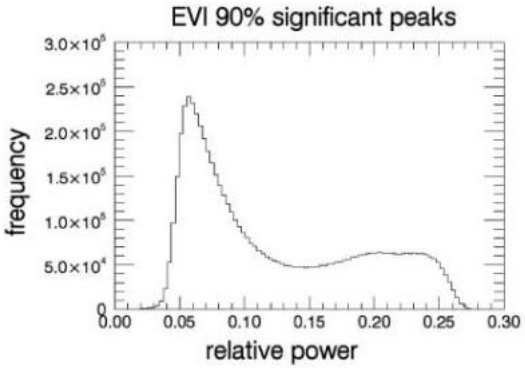
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# Strength of annual cycle

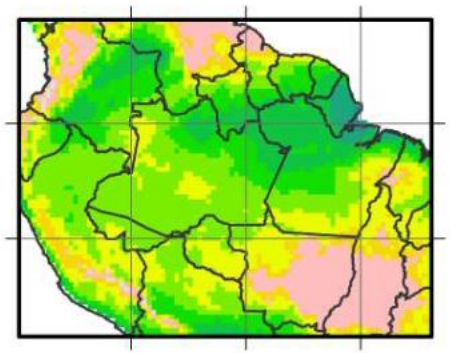
**Is there seasonality: can we observe an annual cycle ? Where?**
**If, yes - how strong is the signal and where are the strong and weak signals?**

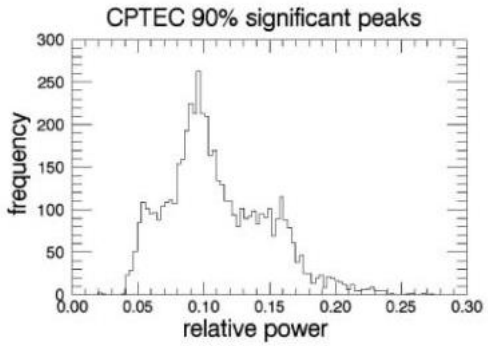
Leaf phenology



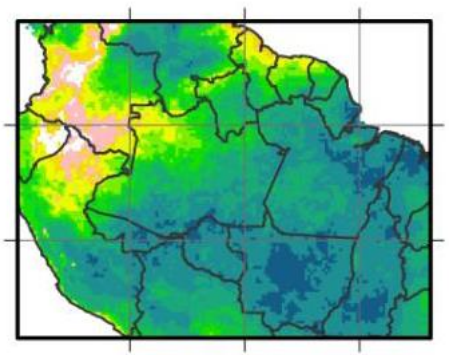


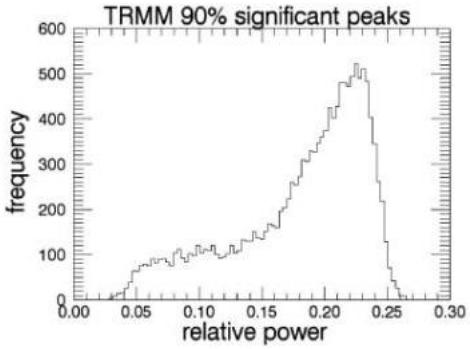

Radiation






Precipitation



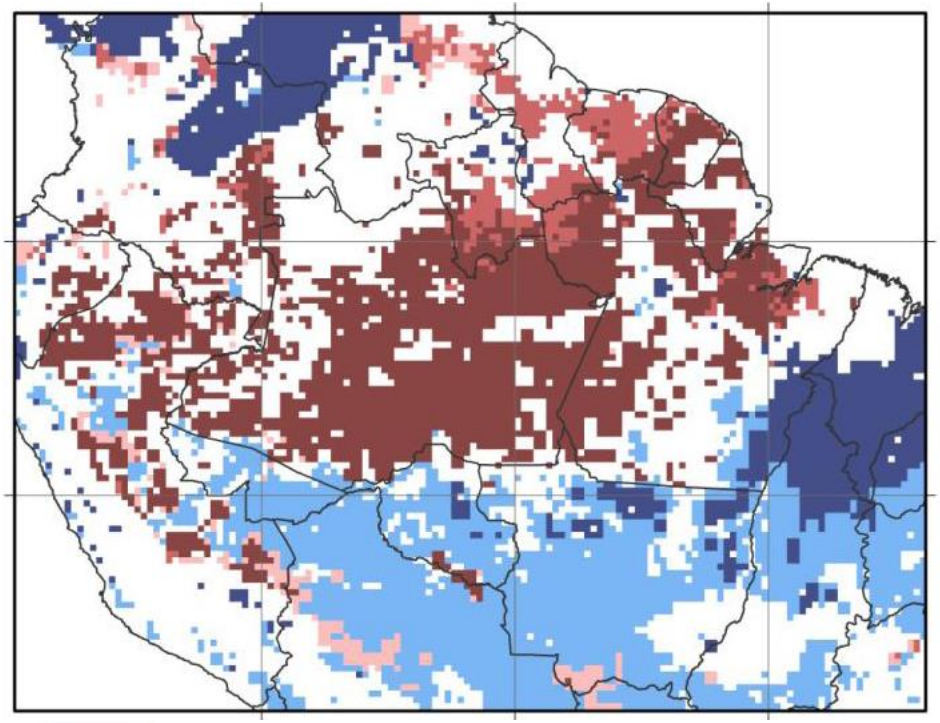


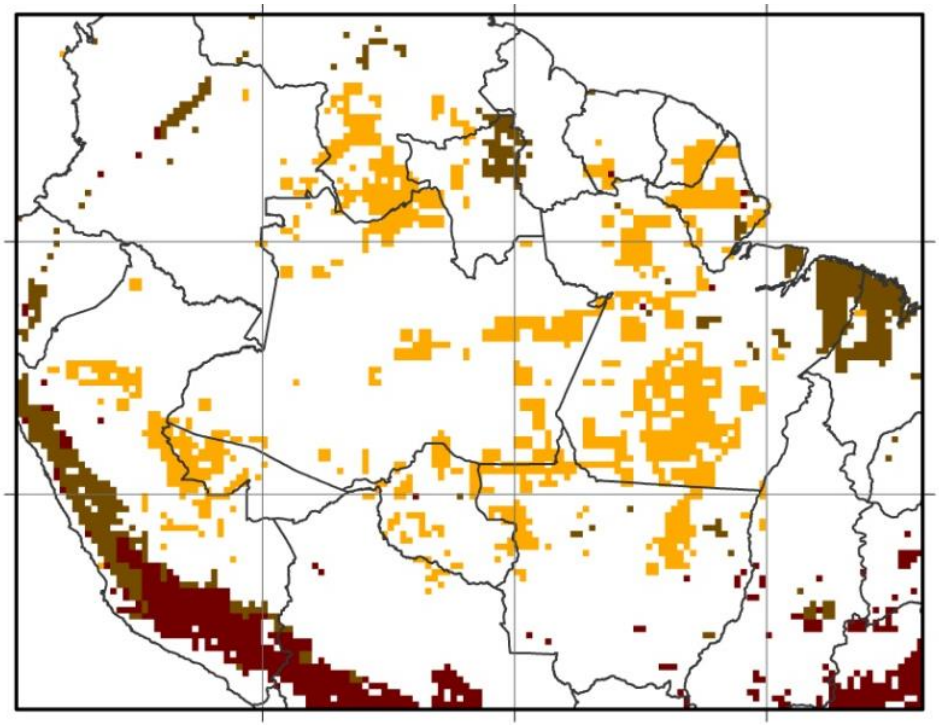

Relative power of annual cycle

| | | |
|---|---|---|
| 0.030 - 0.034 | 0.155 - 0.184 | |
| 0.035 - 0.064 | 0.185 - 0.214 | Sea |
| 0.065 - 0.094 | 0.215 - 0.244 | no peak |
| 0.095 - 0.124 | 0.245 - 0.255 | Peak < 90 % significant |
| 0.125 - 0.154 | 0.255 - 0.3 | |

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# What is driving phenology in tropical America?

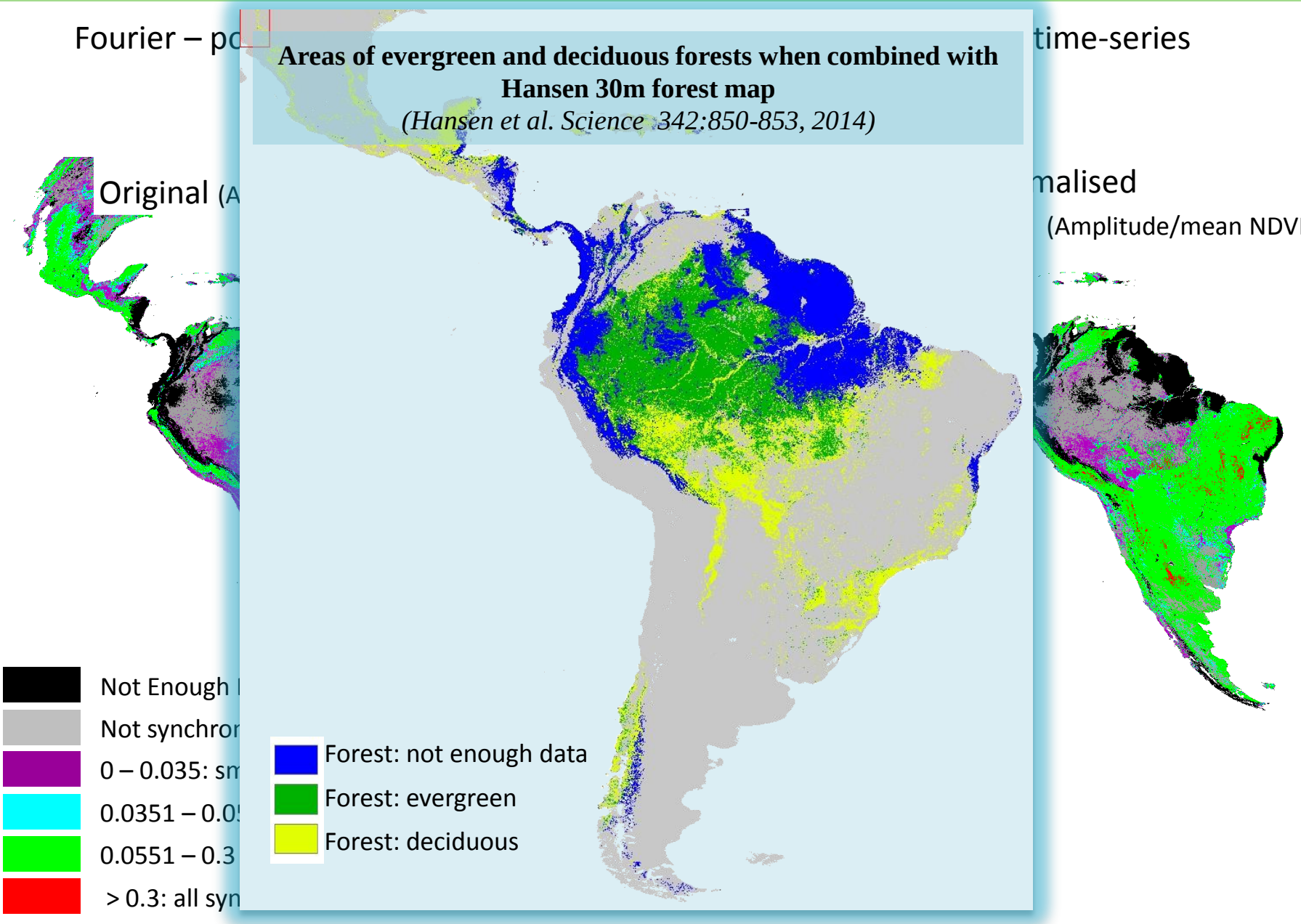




1. Precipitation is 'in phase', radiation 'lags' or is in 'anti-phase'.
2. Precipitation is 'in phase' and radiation 'leads'.
3. Precipitation and radiation 'in phase'.
4. Radiation is 'in phase' and precipitation 'lags' or is in 'anti-phase'.
5. Radiation is 'in phase' and precipitation 'leads'.
6. Precipitation and radiation 'leads'.
7. Precipitation 'leads' and radiation 'lags' or is in 'anti-phase'.
8. Radiation 'leads' and precipitation 'lags' or is in 'anti phase'.

CEH Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# Where are the evergreen & deciduous forests?



# Which of the patterns are real?

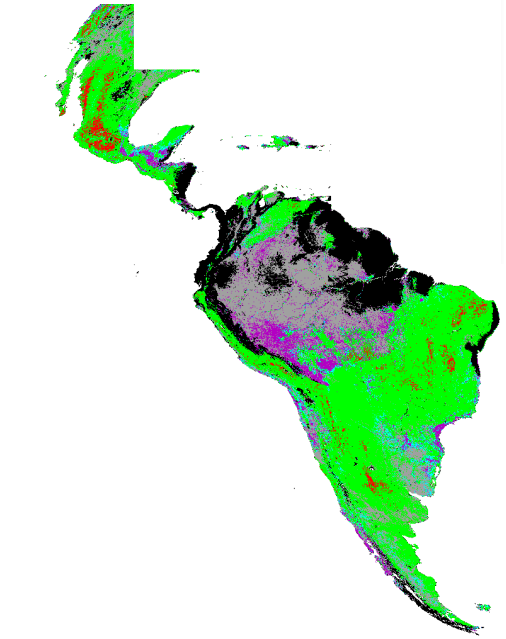
nature climate change

LETTERS

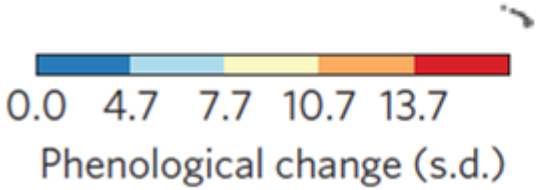
PUBLISHED ONLINE: 2 MARCH 2015 | DOI: 10.1038/NCLIMATE2533

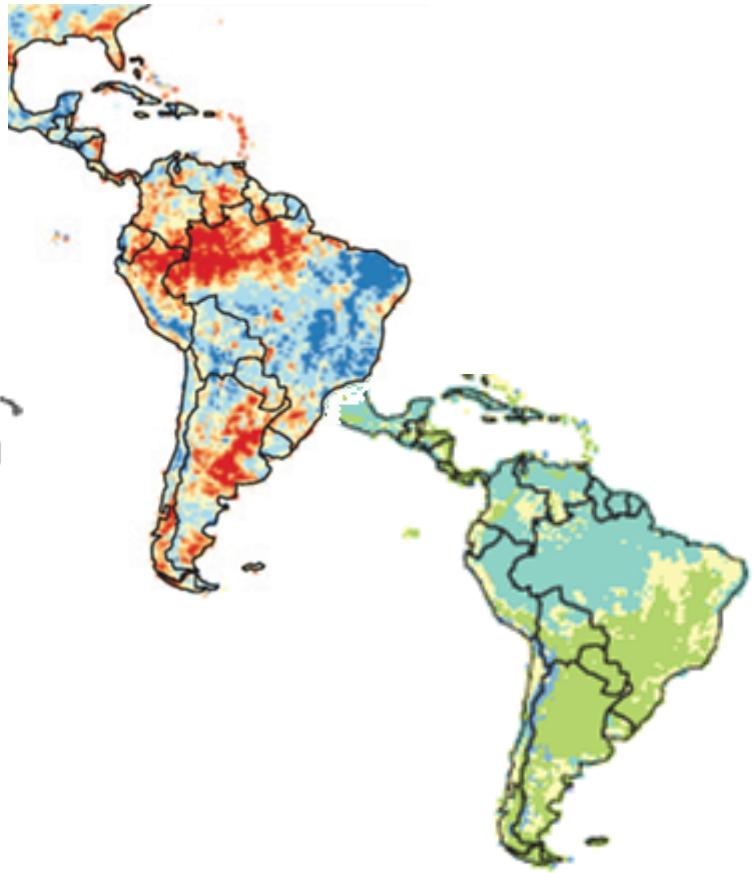
## Three decades of multi-dimensional change in global leaf phenology

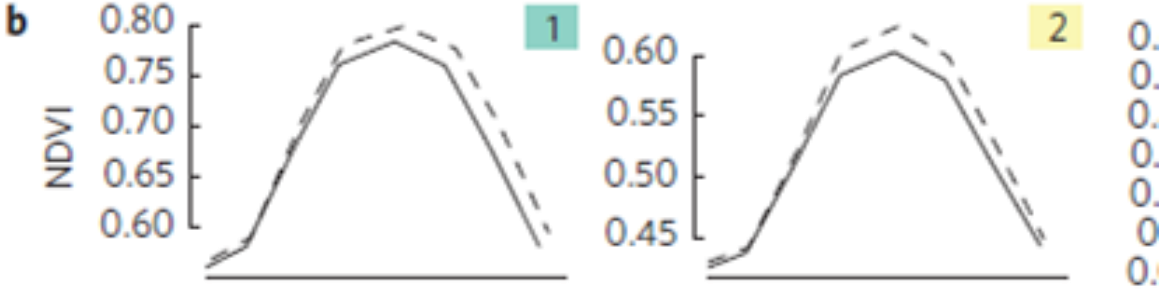
Robert Buitenwerf[1]*, Laura Rose[1,2] and Steven I. Higgins[3,4]



GIMMS NDVI3g



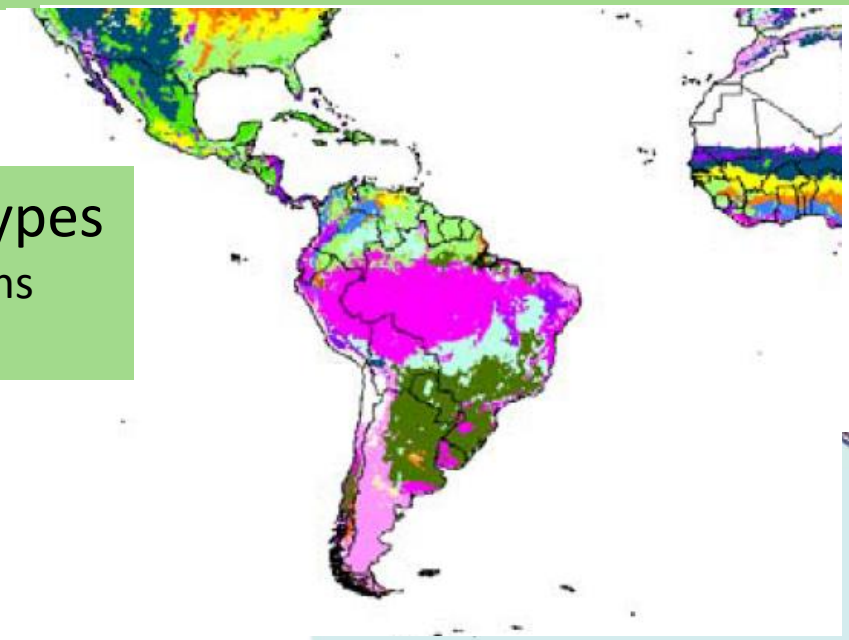


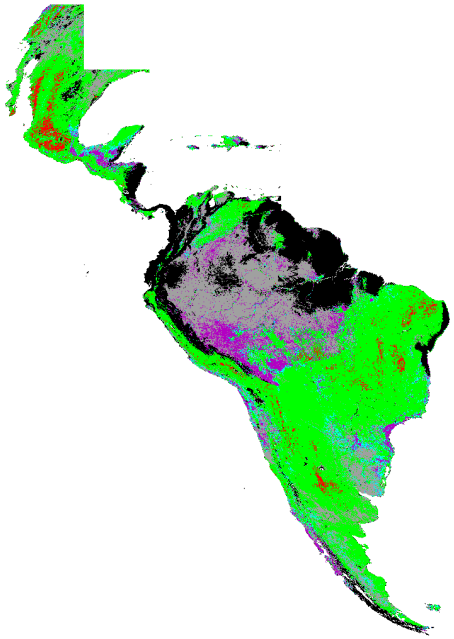

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# Which of the patterns are real?

## Plant functional types

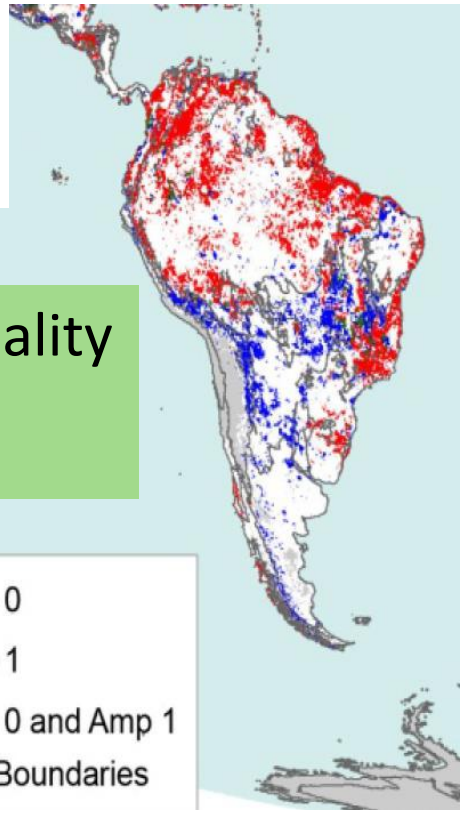
Ivits et al 2014 Rem. Sens
GIMMS NDVI3g





## Global trends in seasonality

Eastman et al 2014 Rem Sens.
GIMMS NDVI3g




Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# How is in situ radiometry relevant?

What is ‘evergreen’ or ‘deciduous’ in the tropics?
How do we interpret the VI (NDVI & EVI) amplitude ?

Some say:
seasonal VI cycles are an artefact of sun angle and shadowing
(Morton et al Nature 2014)

LETTER

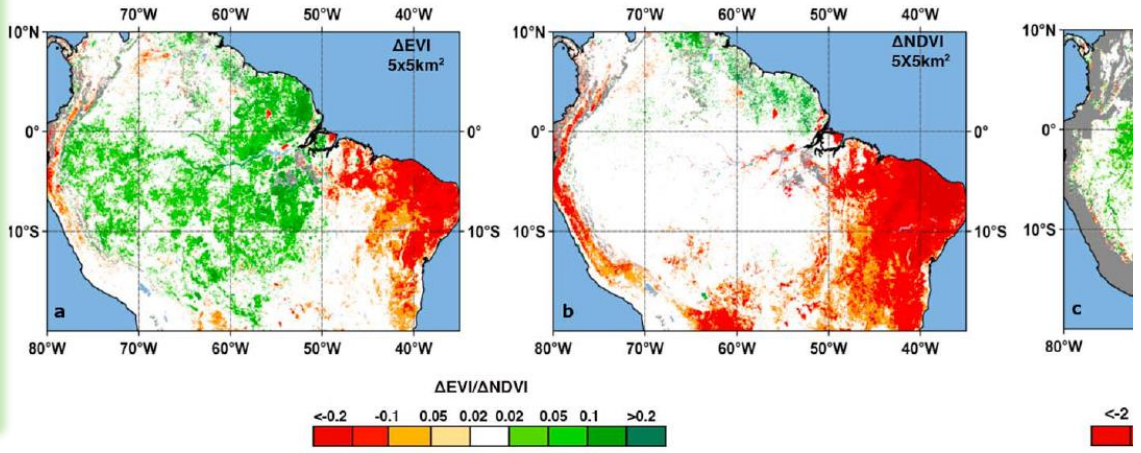
doi:10.1038/natur

**Amazon forests maintain consistent canopy structure and greenness during the dry season**

Douglas C. Morton[1], Jyoteshwar Nagol[2,3], Claudia C. Carabajal[1,4], Jacqueline Rosette[1,2,5], Michael Palace[6], Bruce D. Cook[1], Eric F. Vermote[1], David J. Harding[1] & Peter R. J. North[5]

Others say:
VIs show a combined effect of leaf reflectance changing with age and LAI changes.
(Samanta et al 2012 JGR
…and several others)



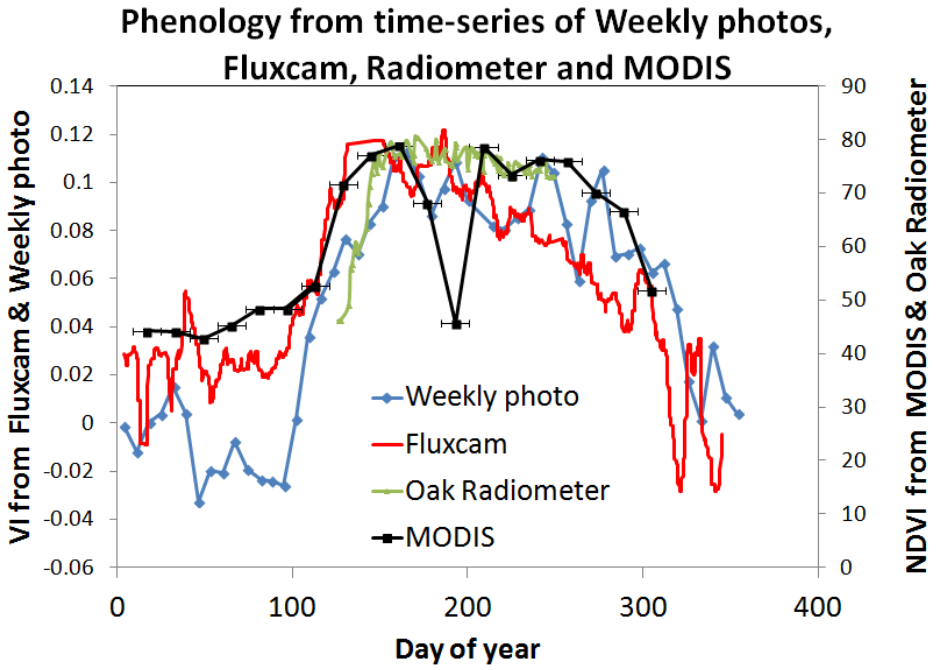


# VI = leaf reflectance; LAI; LAD & clumping, view & sun angles

**Tree leaf:**
How does reflectance change with leaf age?

**Tree canopy:**
How synchronised is the life cycle of leaves (flushing and abscission) within a tree canopy?

**Forest canopy:**
How synchronised is the life cycle of leaves between each tree?

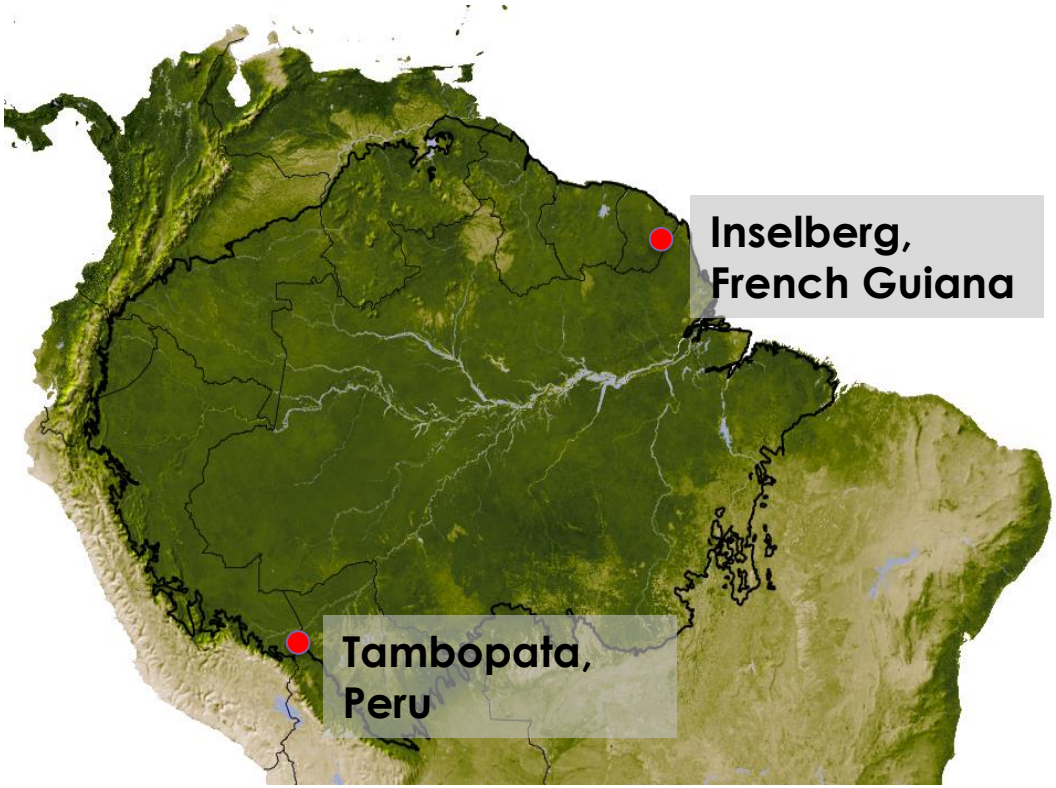



Data from Whytam Wood (UK)
C. George & C. Rowland (CEH)

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# How does reflectance change with leaf age?

*Cecilia Chavana-Bryant – in prep*





2 weeks


Mature


Old

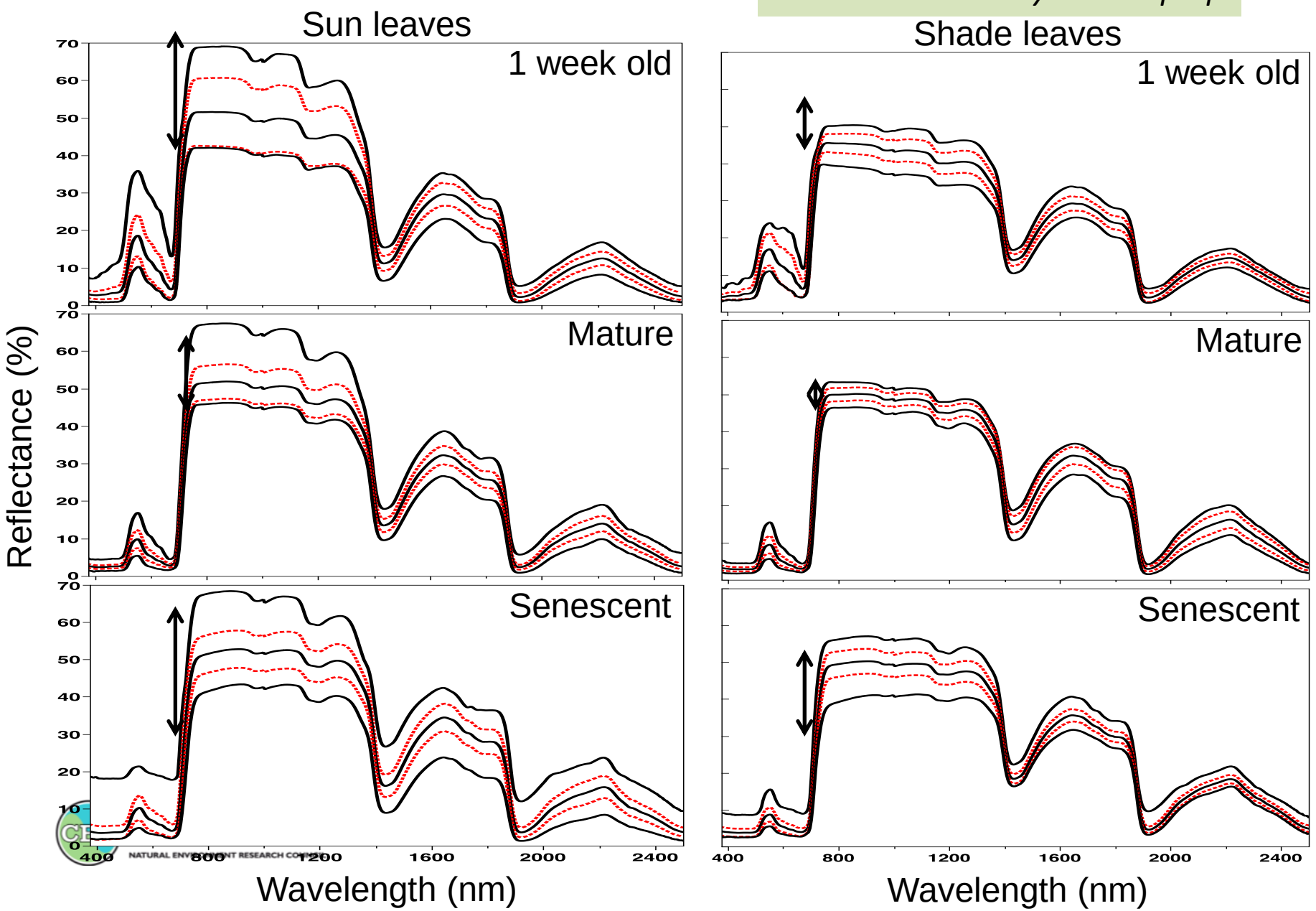

Senescent

5 leaves for each leaf age

N, P, C, $\delta$13C & $\delta$15N

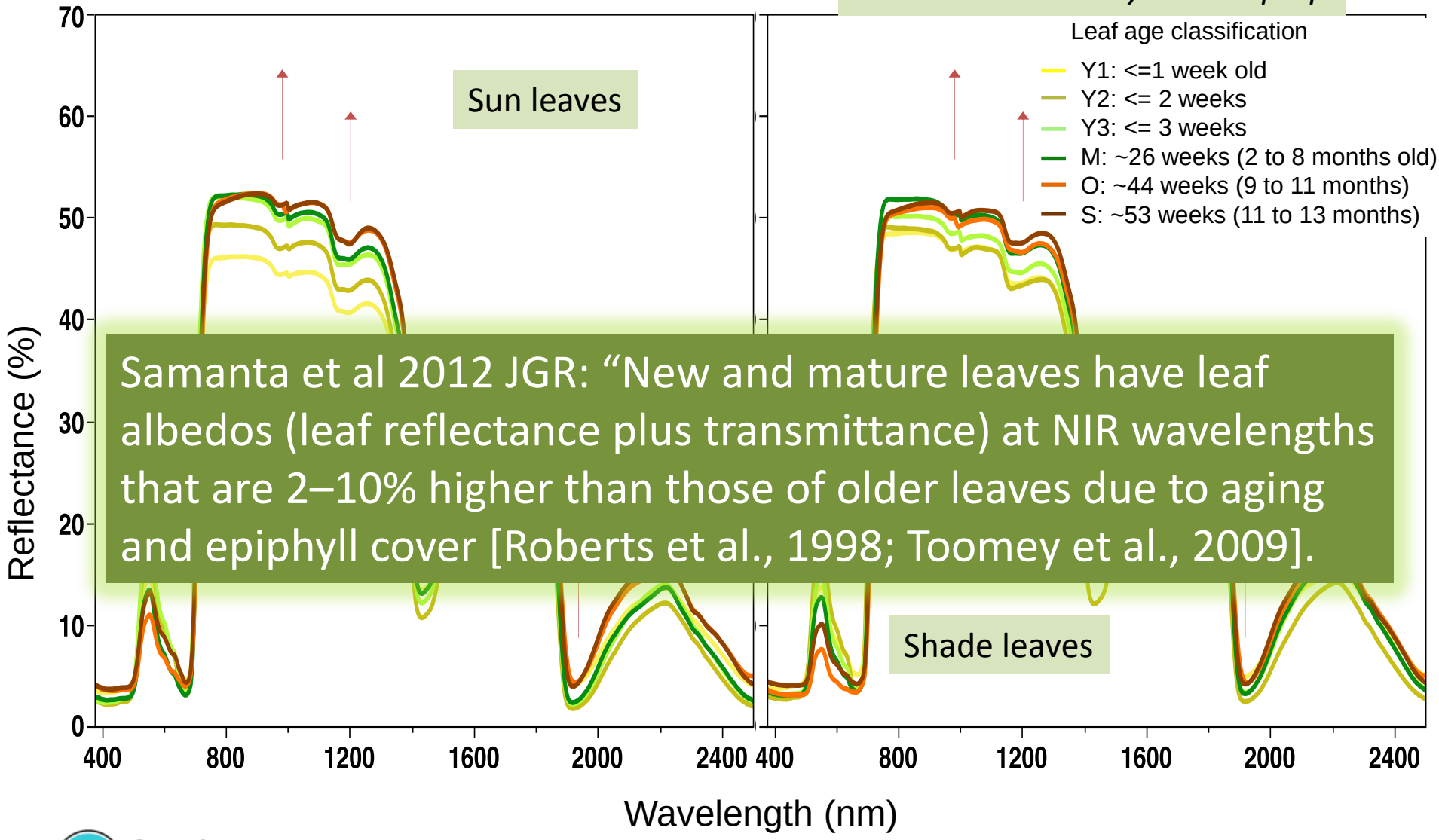
# Spectral leaf life cycle

*Cecilia Chavana-Bryant – in prep*



# Spectral leaf life cycle

*Cecilia Chavana-Bryant – in prep*



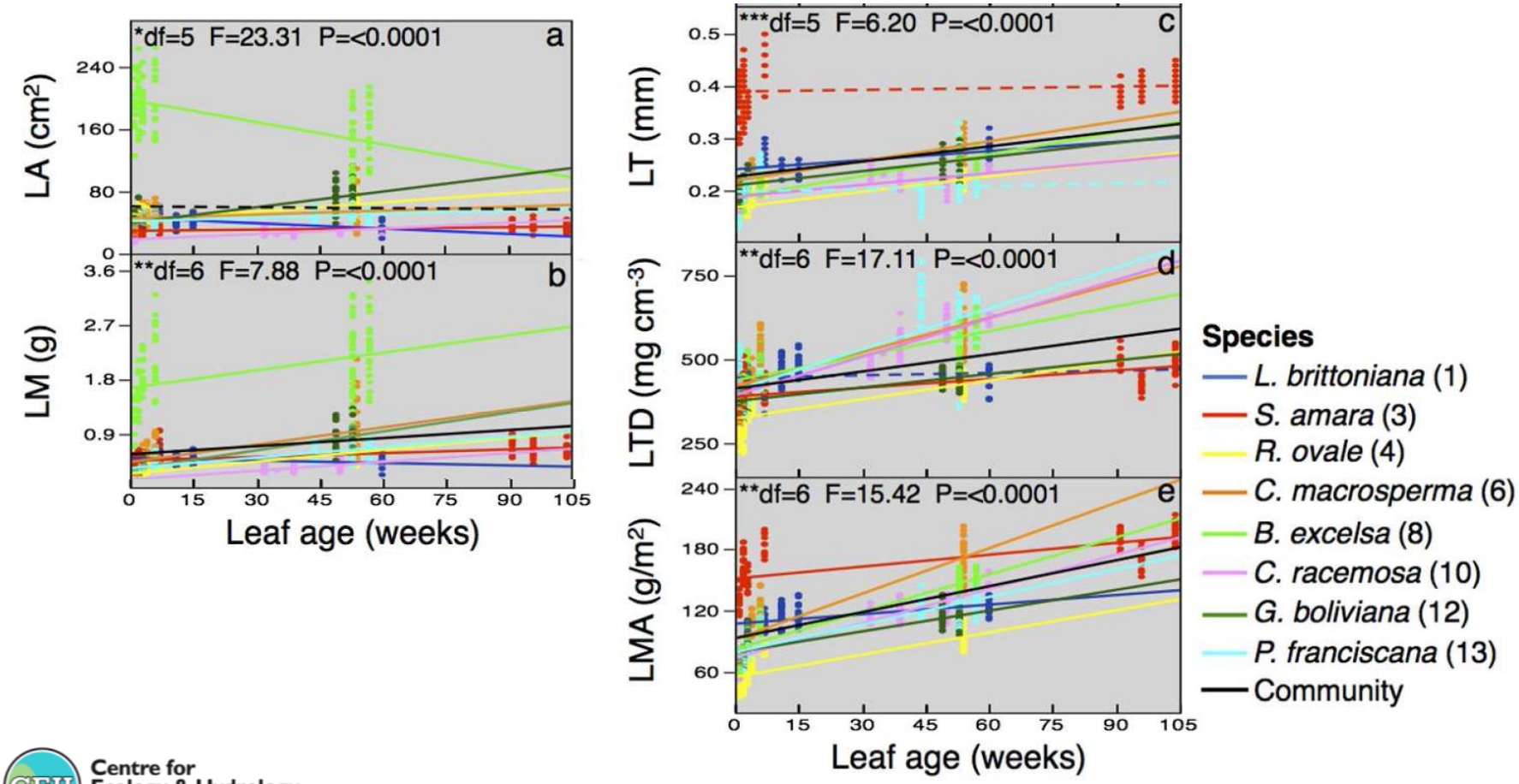

Samanta et al 2012 JGR: "New and mature leaves have leaf albedos (leaf reflectance plus transmittance) at NIR wavelengths that are 2–10% higher than those of older leaves due to aging and epiphyll cover [Roberts et al., 1998; Toomey et al., 2009].

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# Morphological leaf life cycle

*Cecilia Chavana-Bryant – in prep*

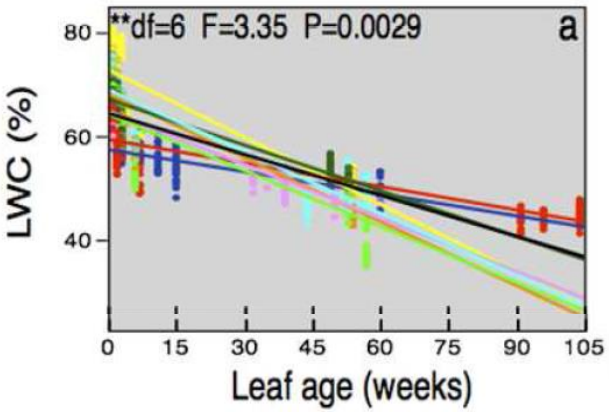
LA: leaf area; LM: Leaf Mass; LT: leaf thickness;
LTD: leaf tissue density; LMA: leaf mass per area

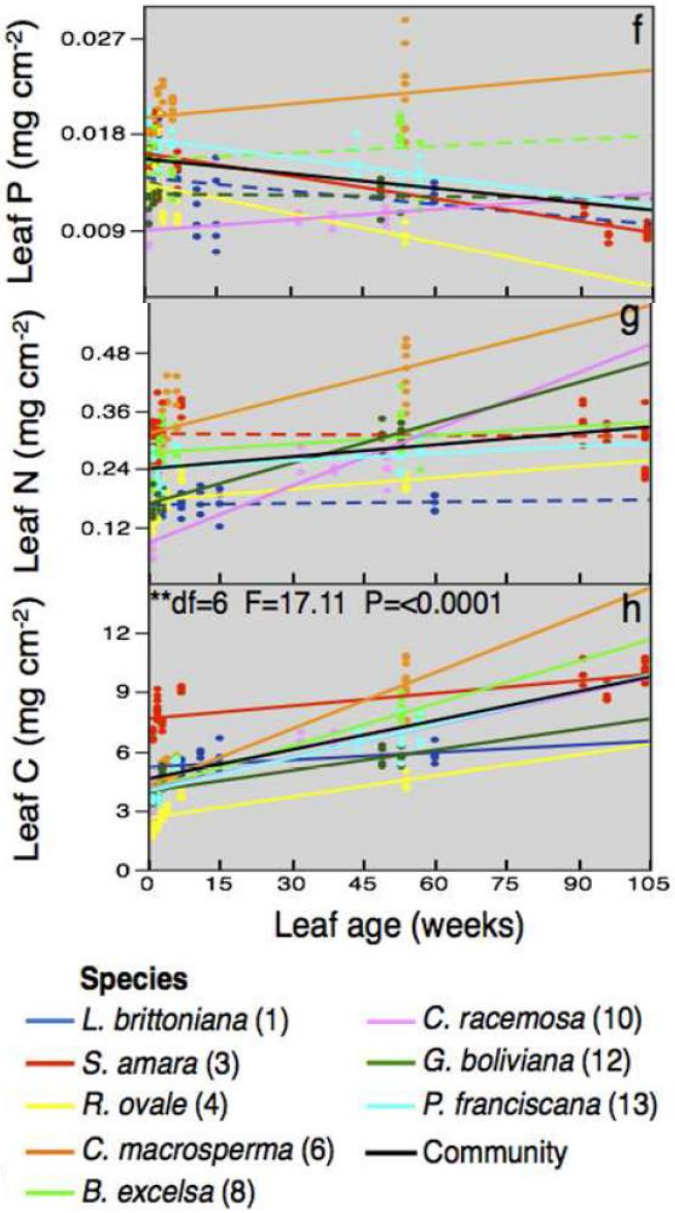



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# Chemical leaf life cycle

*Cecilia Chavana-Bryant – in prep*

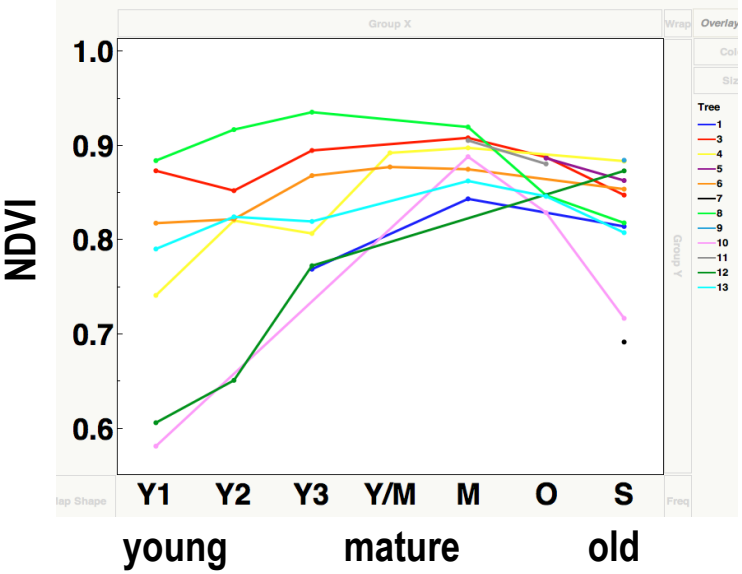



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# NDVI time series: from leaf to tree to forest

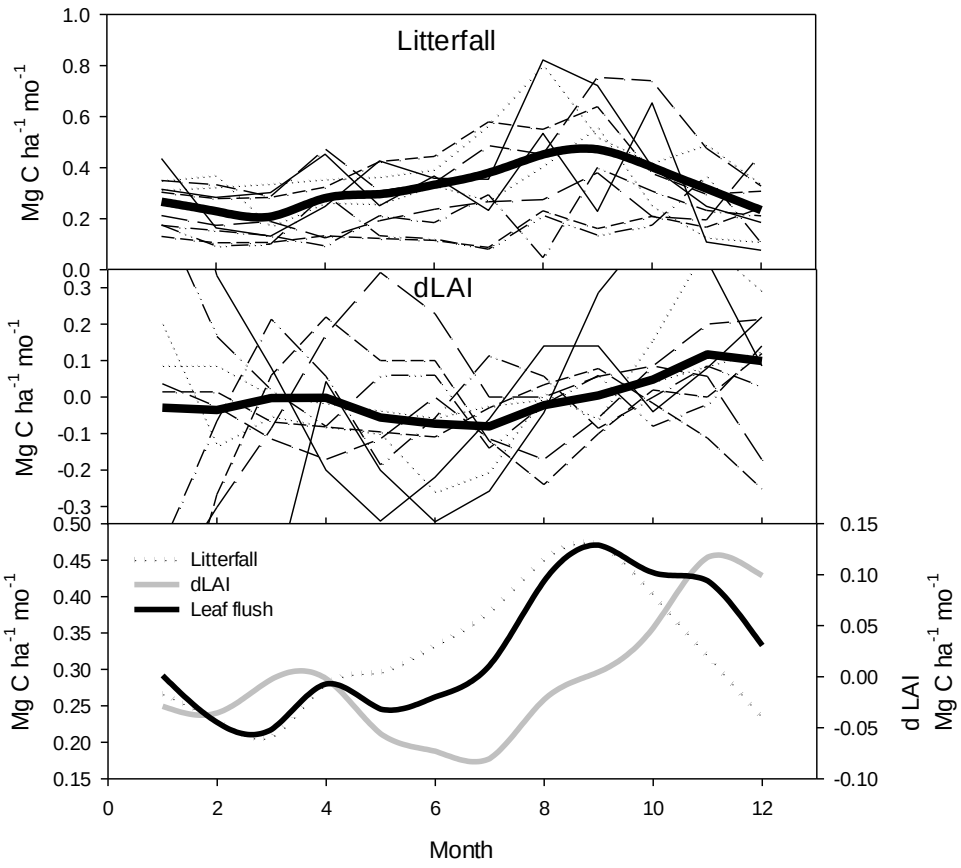
(1) Leaf NDVI average for individual tree




*Cecilia Chavana-Bryant – in prep*

(2) Tree time series of NDVI by combining leaf reflectance with time series of branch leaf demography *(i.e. N$^{o}$ of leaves of a particular age on 1m branch)*

(3) Site time series of NDVI by combining leaf reflectance with data on leaf flush and leaf abscission




*Chris Doughty (OUCE, Oxford): recent analysis of LAI and litter data from 1ha RAINFOR plots*

# Summarising

- Global modellers search for broad brush global patterns, which suits coarse scale resolution imagery *("1km…aaargh… too much detail!")*
- But we need to get the detail right to make sure we can be confident in the broad brush.
- Are the subtleties seen by the radiometry important? Maybe, maybe not.
- Covering both the spatial and temporal variations is key.

# Thank you

**France Gerard**, Centre for Ecology and Hydrology, UK;

- **Charles George,** CEH, UK
- **Cecilia Chavana-Bryant,** Oxford Univ., UK
- **Graham Weedon,** Met. Office, UK;
- **Garry Hayman,** CEH, UK
- **Yadvinder Malhi,** Oxford Univ., UK
- **Andrew Bradley,** Imperial college,UK

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL