Global monitoring of Terrestrial ecosystem: challenges and opportunities

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Geography and Environment@soton

❖ Global Environmental Change and Earth Observation one of the five research group

❖ Five Academic staffs +1 (advertised) work with ***Geodata*** institute,Three research staffs, Seventeen graduate students

❖ Key research areas ‘development and application of models and algorithms for retrieving information from earth observation data from airborne and satellite platforms, field instrumentation and surveys’

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With Contribution from ….

C. Jeganathan, P. Atkinson, B. Ogutu, E.J. Milton,

W. Frampton and F. Vuolo (UoS)

A. Harris (University of Manchester)

T. Lankaster and S. Hubbard (Infoterra Ltd.)

P. Curran (City University)

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What is terrestrial Ecosystem?

Gas exchange

Precipitation

Evaporation

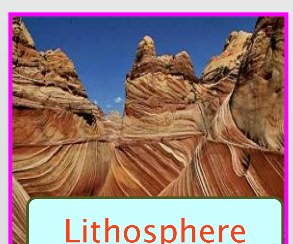
Nutrient Exchange

Leaching

Weathering

Sedimentation

Runoff



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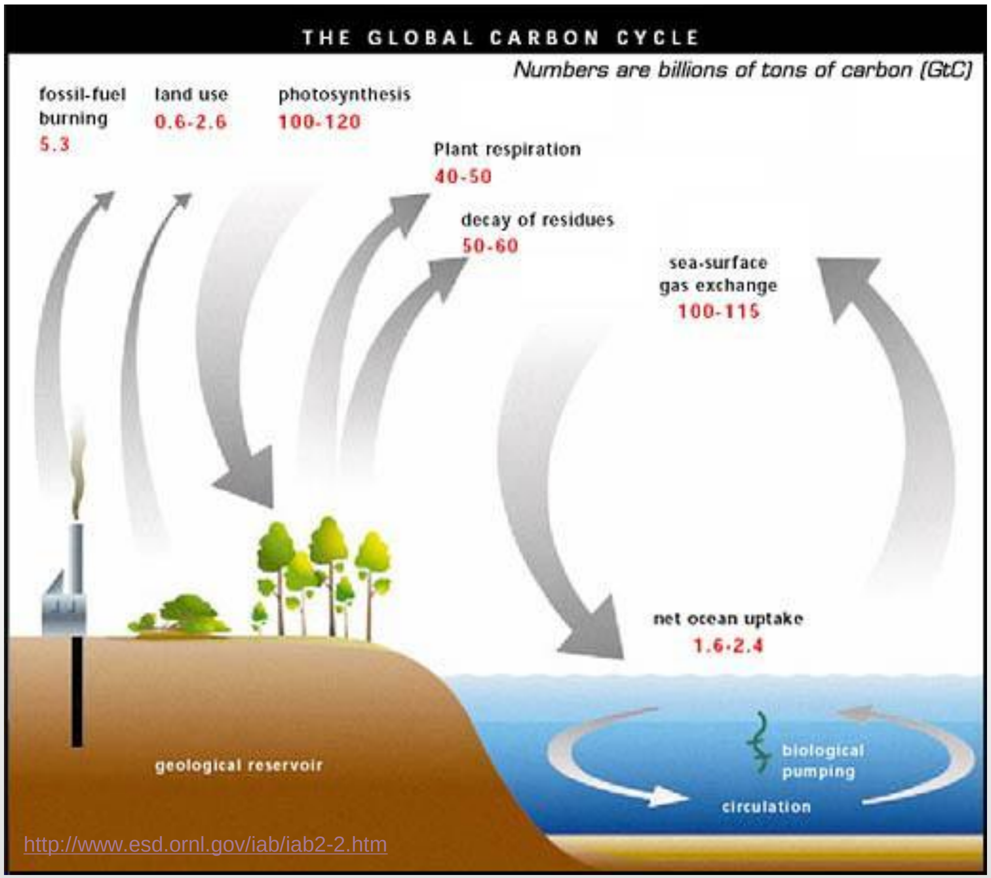
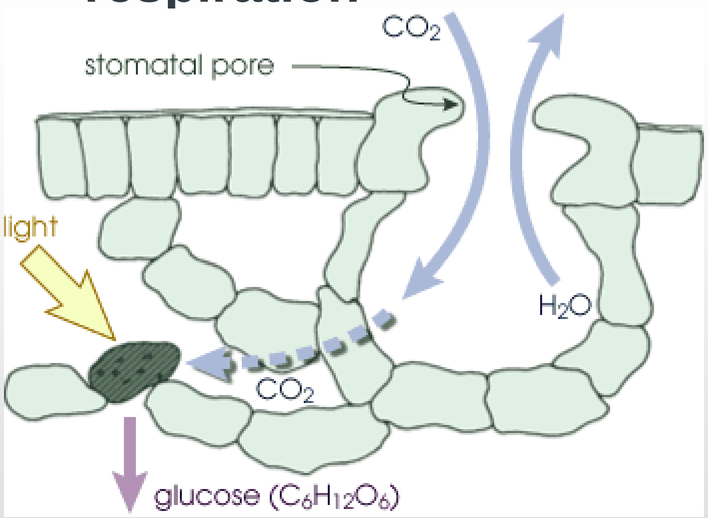
Why study terrestrial Ecosystem?

Terrestrial ecosystems occupy 144,150,000 km^2, or 28.2%, of Earth's surface.



On the land the major exchange of carbon with the atmosphere results from photosynthesis and respiration



- To understand regional to global scale environmental phenomena

What Remote Sensing offer?

- Inter- and intra-annual global vegetation monitoring on a periodic basis
- Global biogeochemical, climate and hydrological modelling
- Net primary production and carbon balance
- Anthropogenic and climate change detection
- Agricultural activities (plant stress, harvest yields, precision agriculture)

What we could measure?

1. Amount
2. Structure
3. Pigment content (chlorophyll etc.)

What Remote Sensing offer?

❖ We use individual/multiple bands, but more frequently Vegetation indices

❖Most probably NDVI (Normalised Difference Vegetation Index) is the widely used VI

❖Key sensors for global studies

- AVHRR -> longest NDVI time series (issues with Data quality)
- SPOT VEGITATION-> From 1998, 1km Spatial resolution
- MODIS-> From 2000, 250m Spatial resolution, NDVI, EVI

Most of the information are on Structure and amount and not on chlorophyll content

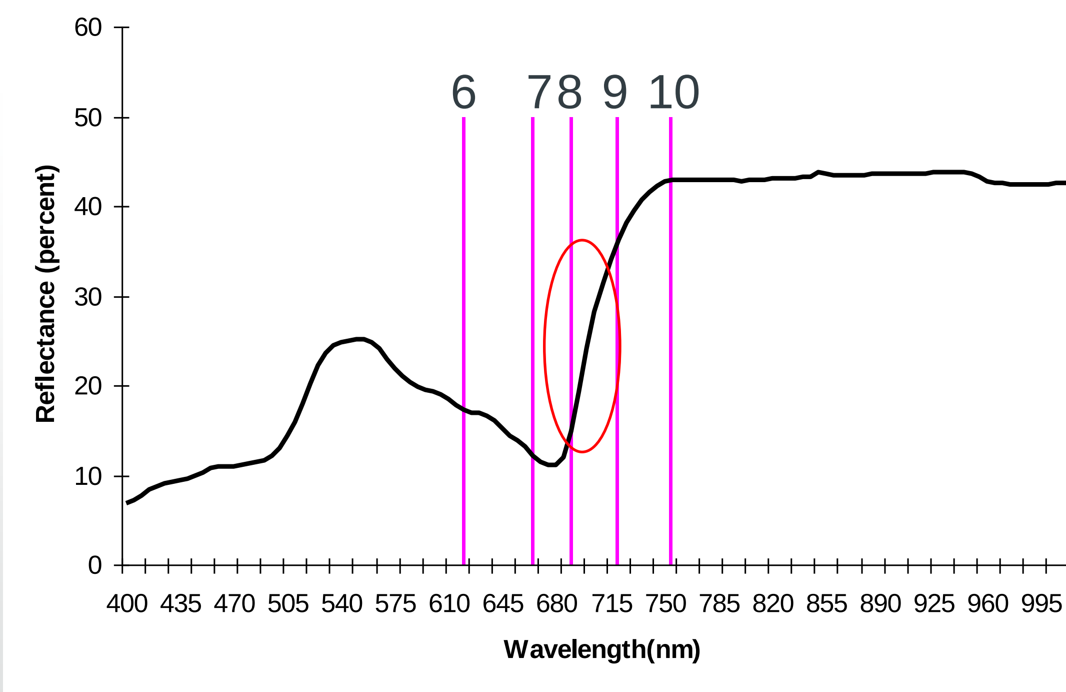
A step change !

- MEdium Resolution Imaging Spectrometer (MERIS) launched 2002 onboard ESA's ENVISAT

❖15 programmable bands in region of 390-1040nm

❖1150km swath on ground

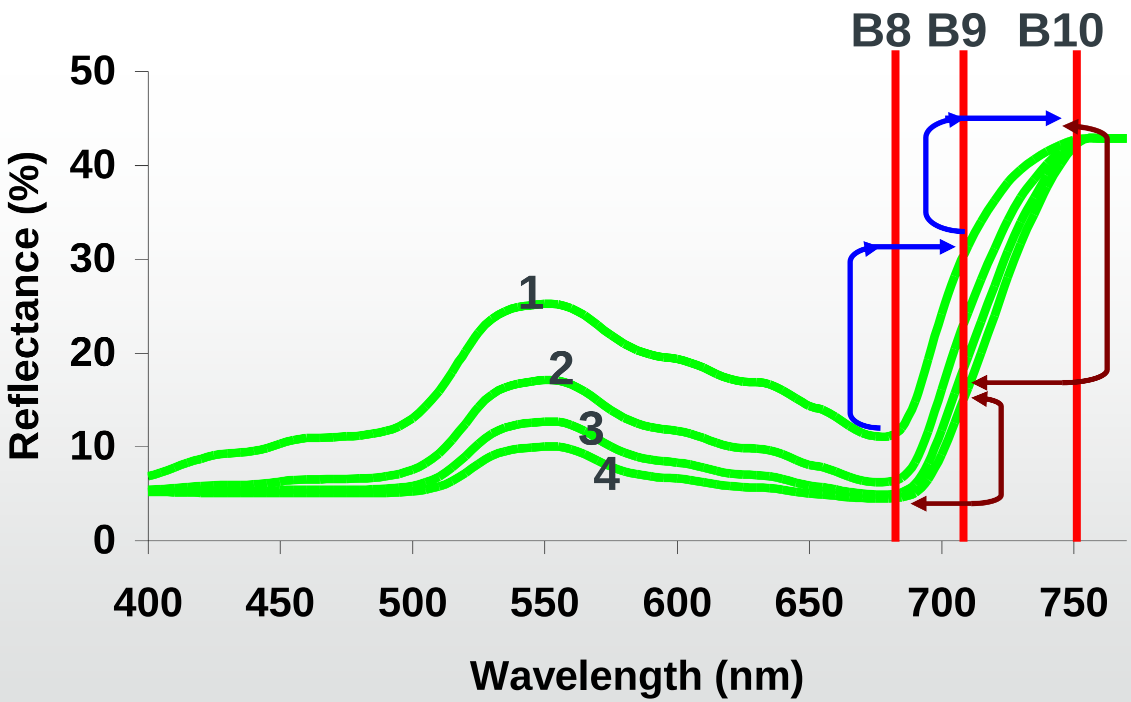
❖300m,1.2 km spatial resolution



Position of MERIS standard band setting on a vegetation reflectance spectrum

A chlorophyll Index: Opportunity I

- Aim
  - Easy to calculate from MERIS data
  - Sensitive to wide range of chlorophyll



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MERIS MTCI: Opportunity I

❖ MTCI makes use of the high spectral resolution of the Medium Resolution Imaging Spectrometer to track the position of the Red Edge (Dash and Curran, 2004).

$$MTCI = \frac{R_{Band\,10} - R_{Band\,9}}{R_{Band\,9} - R_{Band\,8}}$$

❖ The magnitude of the MTCI is positively related to the total chlorophyll content.

❖ This, in turn, is a function of chlorophyll concentration and leaf area index which reflect plant growth and biomass.

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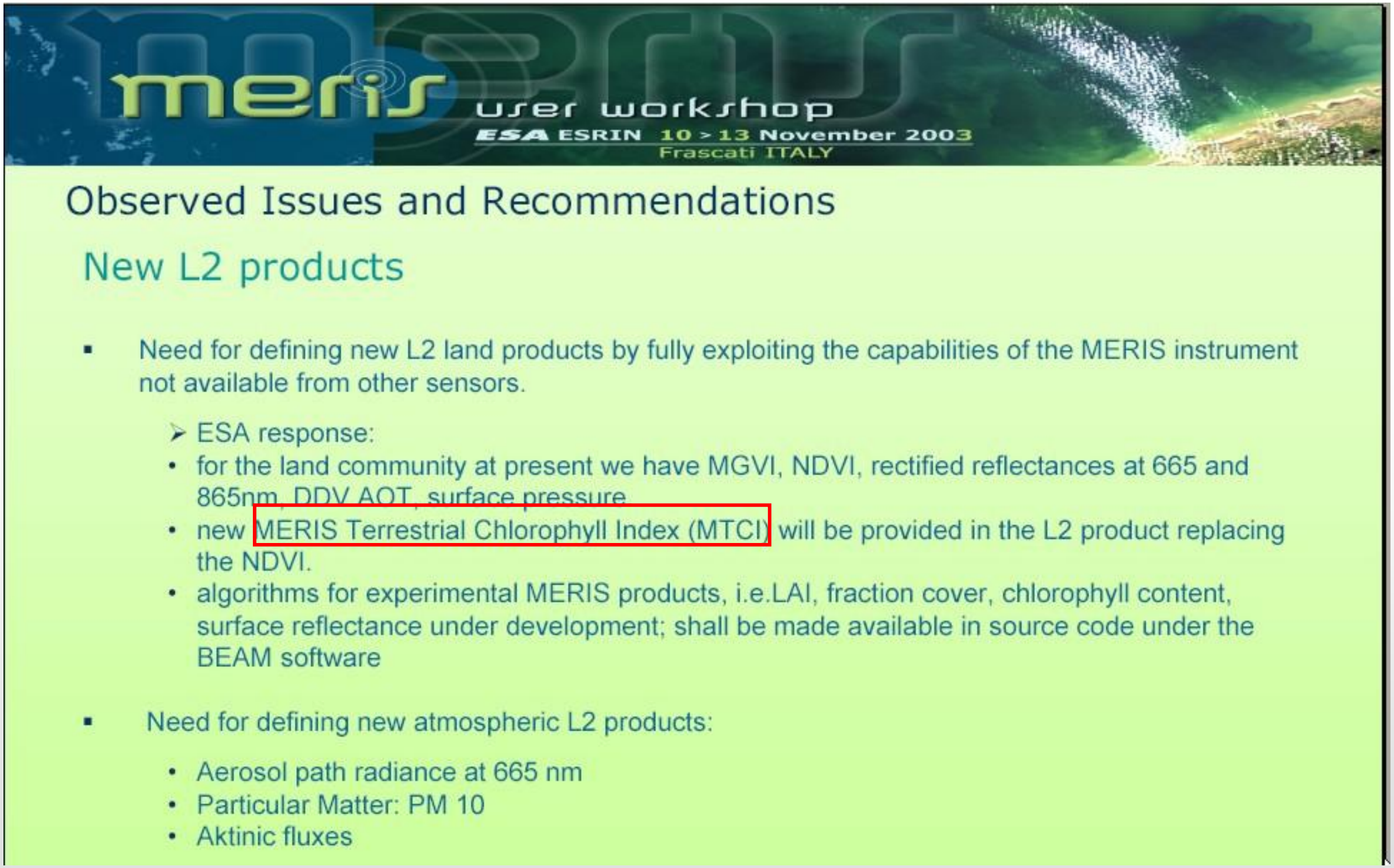
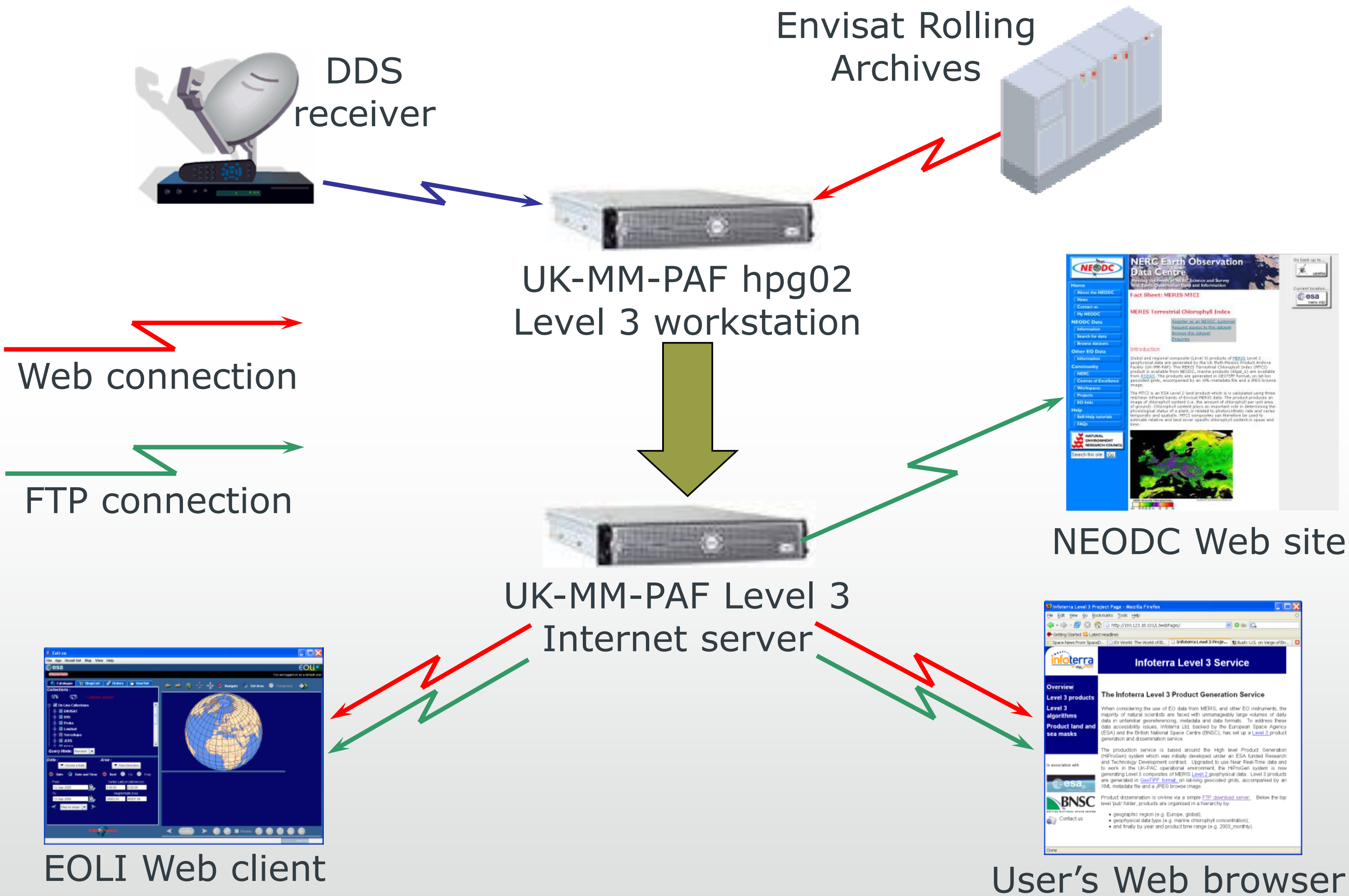
MTCI: ESA L2 Product

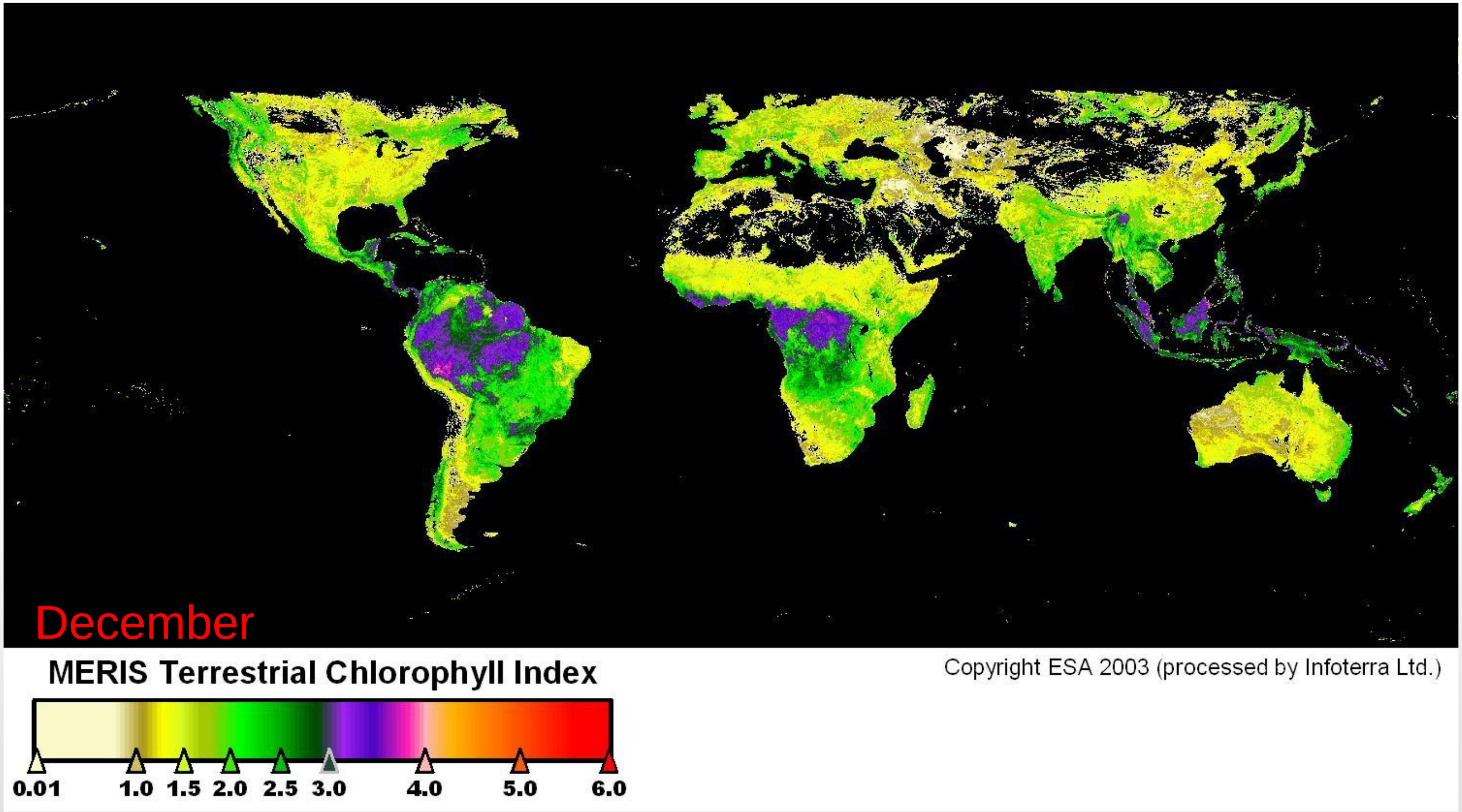
November-2003



NRT data distribution



MERIS Terrestrial Chlorophyll Index (MTCI)



Global MTCI in 2003

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A chlorophyll Index: Challenge I

- **Calibration**
  The relationship between DN measured at the sensor and the actual geophysical value of the object viewed. Calibration can be absolute or relative.

- **Vicarious calibration**
  Calibration achieved using a method that is independent of that used to establish the primary calibration.

- **Validation**
  The process of assessing, by independent means, the uncertainties of the data products derived from the system outputs (NASA, 2003)

Validation of MTCI: Challenge I

- 6 Field validation campaigns
  - Dorchester, UK (crop) **(MERIS, Field)**
  - New Forest, UK (forest) **(MERIS, CASI, Field)**
  - Campania region, Italy (tree/crops) **(MERIS, Rapid Eye, Field)**
  - Barrax, Spain (Crops) **(MERIS, ATM/CHRIS, Field)**
  - Sicily, Italy (tree/crops) **(MERIS, Eagle/Hawk, Field)**
  - Harwood Forest, UK (Coniferous forest) **(MERIS, Eagle/Hawk, Field)**

The process of Validation

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Field data and processing

Issues

Leaf Area Index (LAI-2000)

Relative leaf chl (SPAD)

Adequate sampling scheme

Relative to absolute Leaf chl

Crop specific equations

Canopy chl content (LAI * Leaf chl)

ESU: 20 x 20 m

VHR multispectral data

Issues

Geometric correction (GCPs)

Atmospheric correction (ATCOR)

Adequate ancillary data for ATM correction

Estimation of canopy parameters (model inversion)

Model inversion parameterization

Canopy chl content (LAI * Leaf Chl)

Pixel size 20 x 20 m

Validation of VHR canopy chlorophyll maps

Aggregation of VHR chlorophyll maps

Medium and Coarse chlorophyll maps

If adequate field size

ESU: 300 x 300 m

Pixel size 300 x 300 m

MERIS

Direct calibration and validation procedure at medium resolution

The process of Validation-1

January 2007


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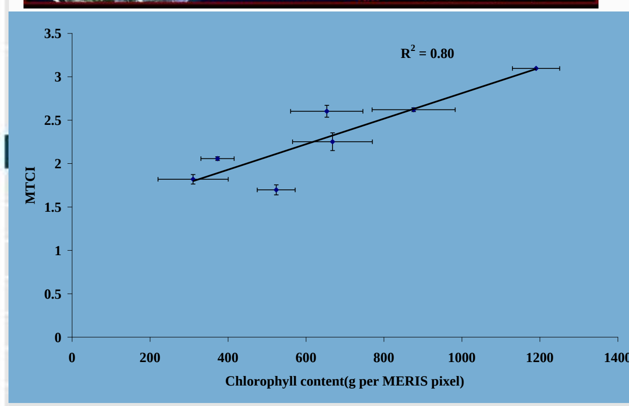
Measuring leaf area index

MERIS chlorophyll data proves positive

30 January 2007
Scientists have, for the first time, devised and tested a method for correlating spaceborne data derived from Envisat's MERIS instrument on the amount of chlorophyll present in terrestrial vegetation with actual chlorophyll measured in field experiments. Positive correlations further confirm that MERIS is providing an accurate picture of the health our planet.



The process of Validation-2

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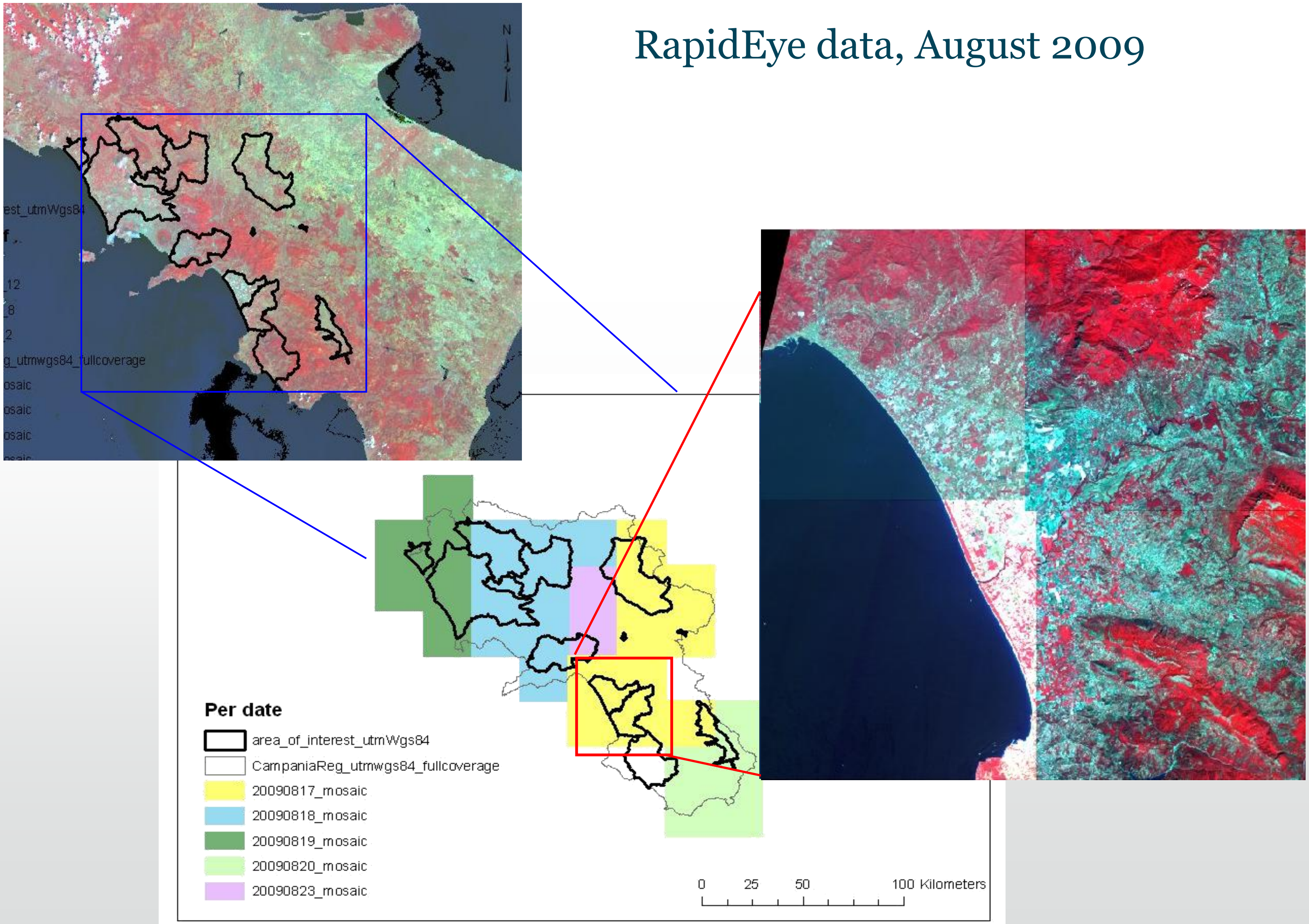
Campania region, Italy (2009)

RapidEye data, August 2009



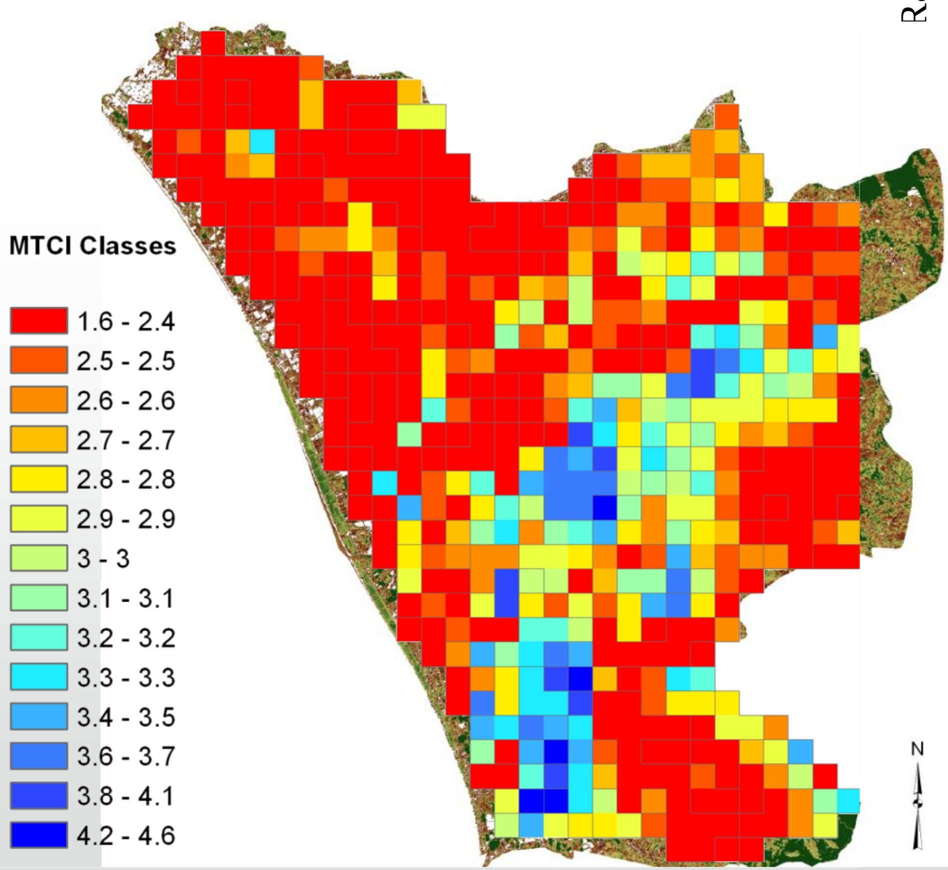
The process of Validation-2

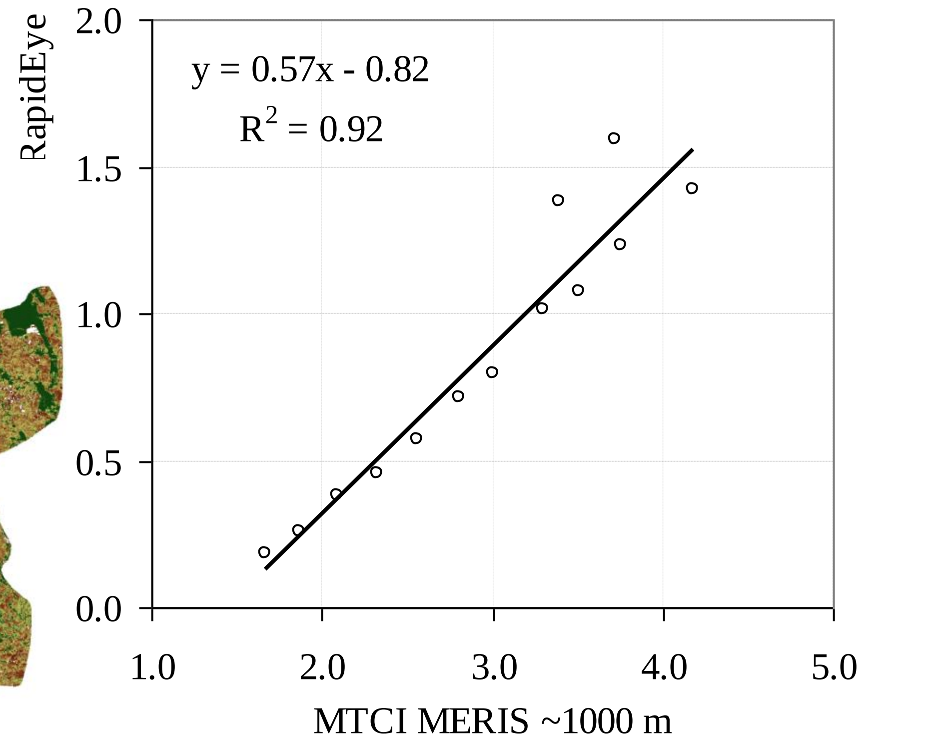
Variability

		
Peach tree	Actinidia	Poplar (biomass)
		
Maize	Artichoke	Poplar

The process of Validation-2

Aggregation based on MTCI values





The process of Validation-2

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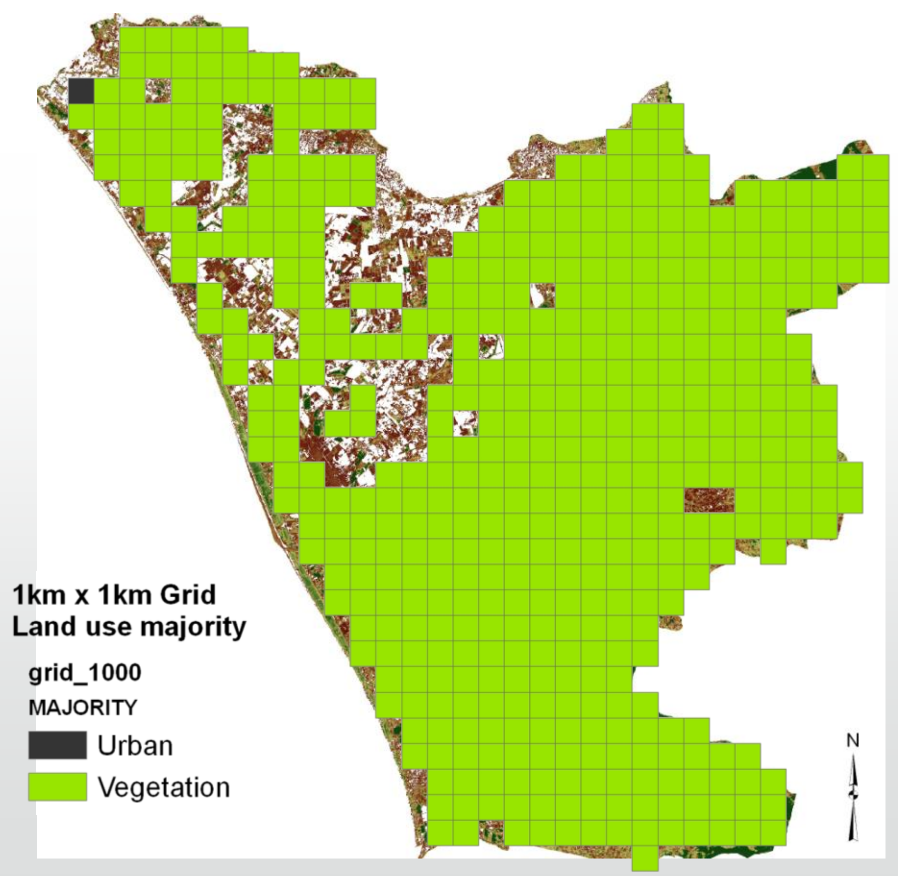
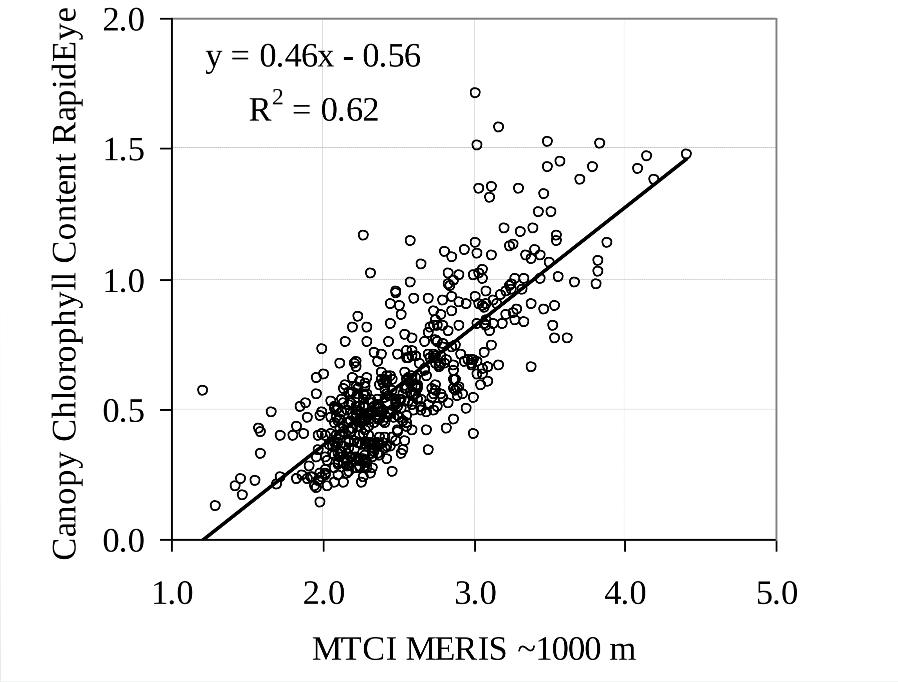
Aggregation at gridcell level



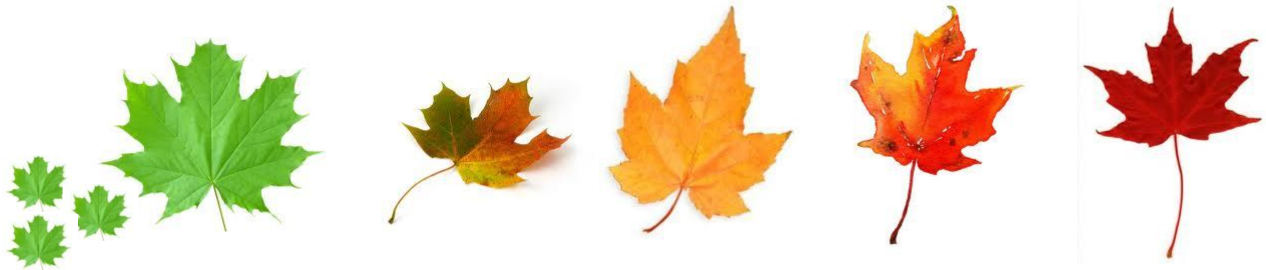


Applications

Space-time RS data

Phenology from Space: Opportunity II

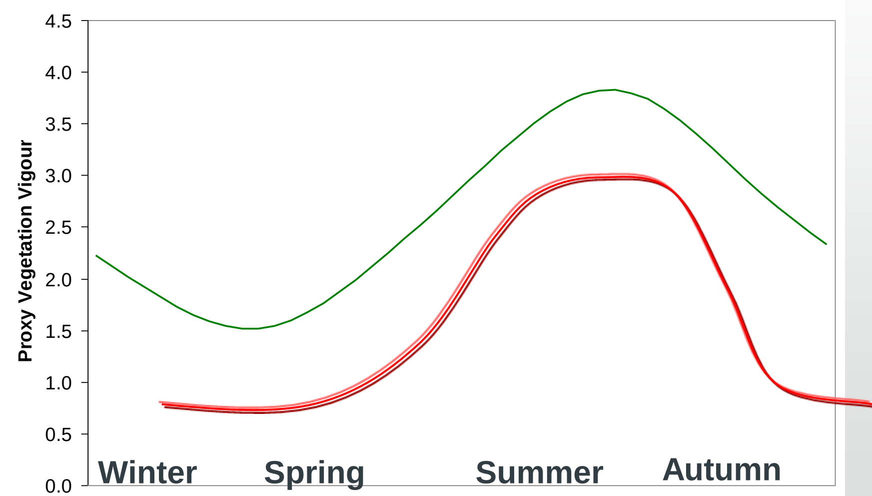
Leaf Cycle



Anthocyanins

Chlorophyll Carotenoids/Xanthophylls

Credit:dmlawncare.com



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Methodology

STEP-1 **Data cleaning and flagging**

STEP-2 **Data smoothing**

STEP-3 **Temporal base information extraction**

STEP-4 **Phenological variable extraction**

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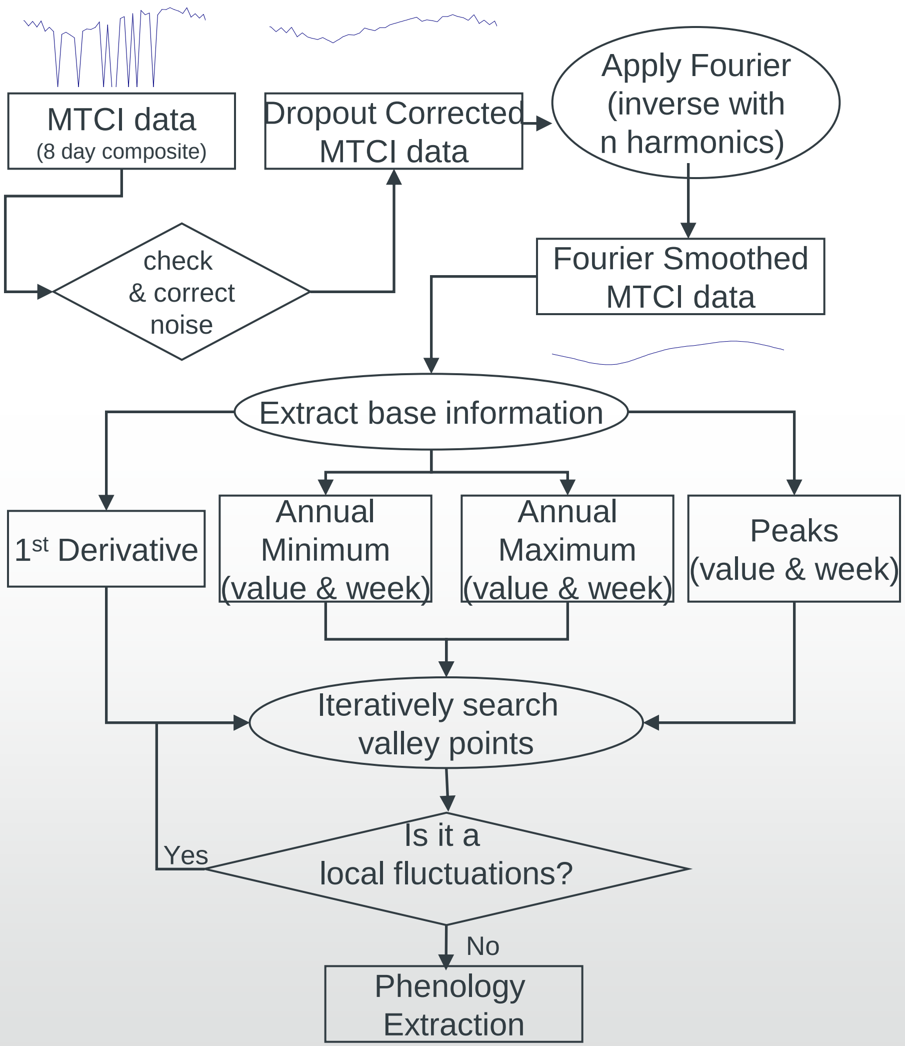
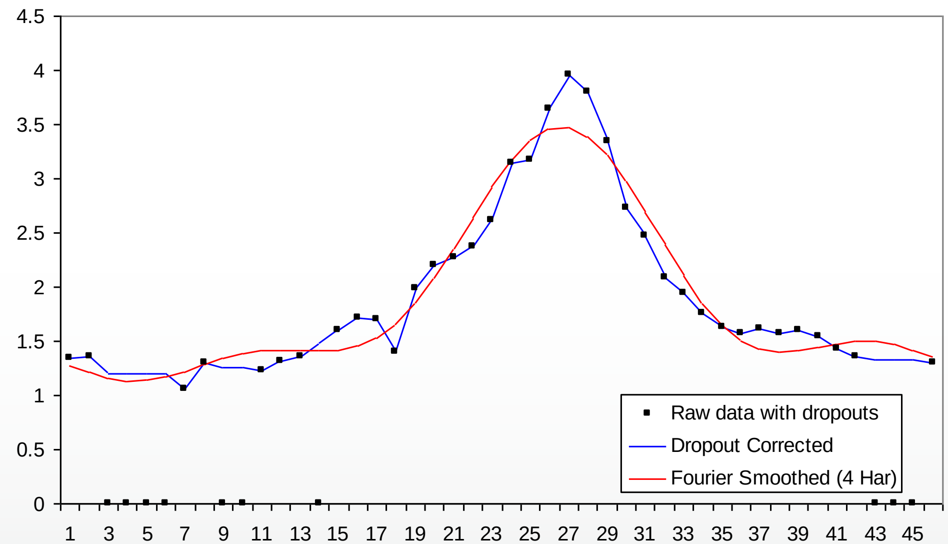
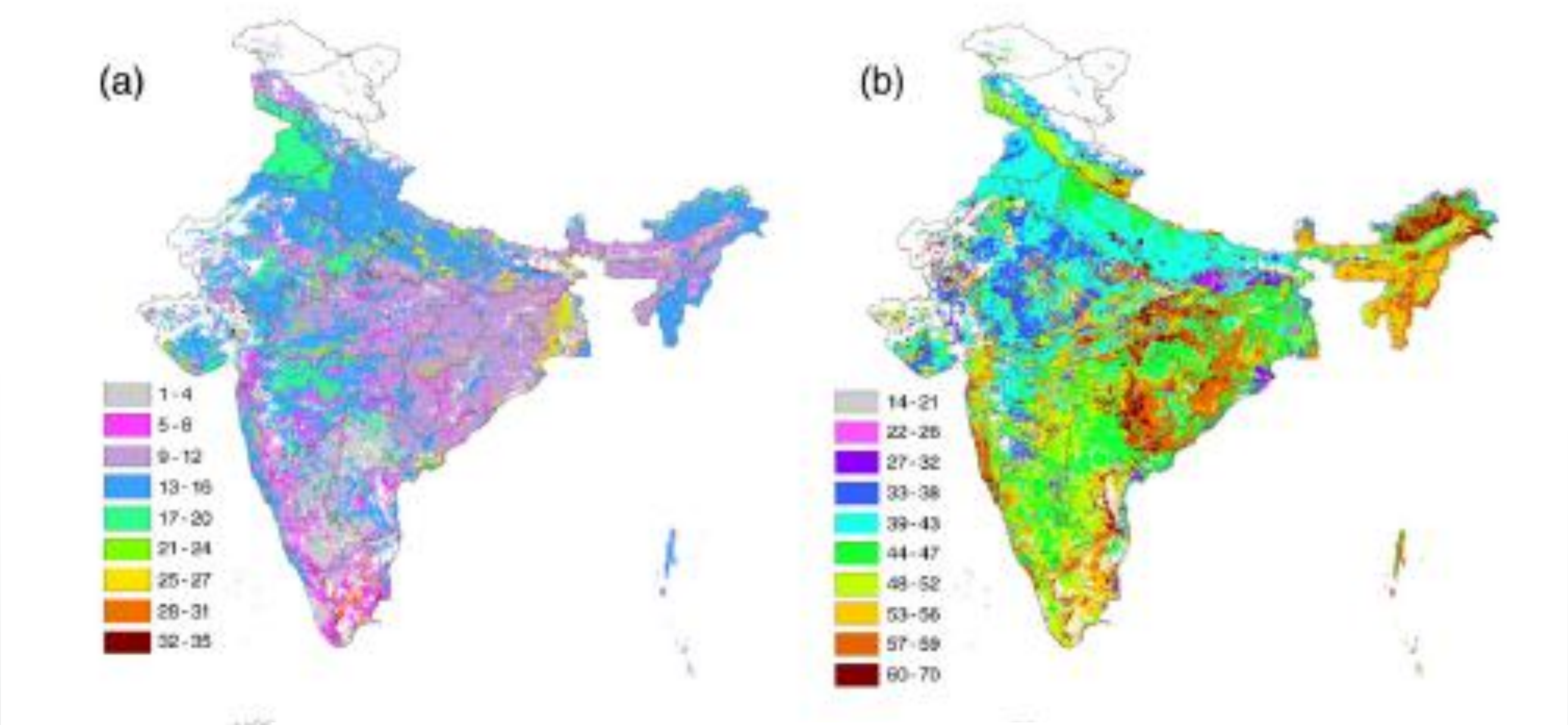
Methodology





Dash et al., (2010), RSE, 114 , 1388-1402

Results- India



First Growing season

Results- India

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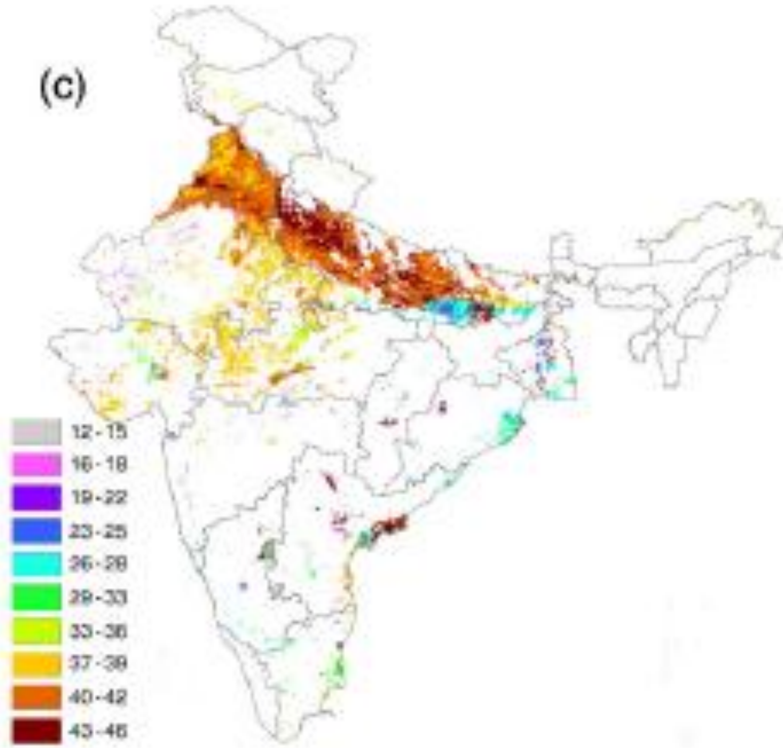

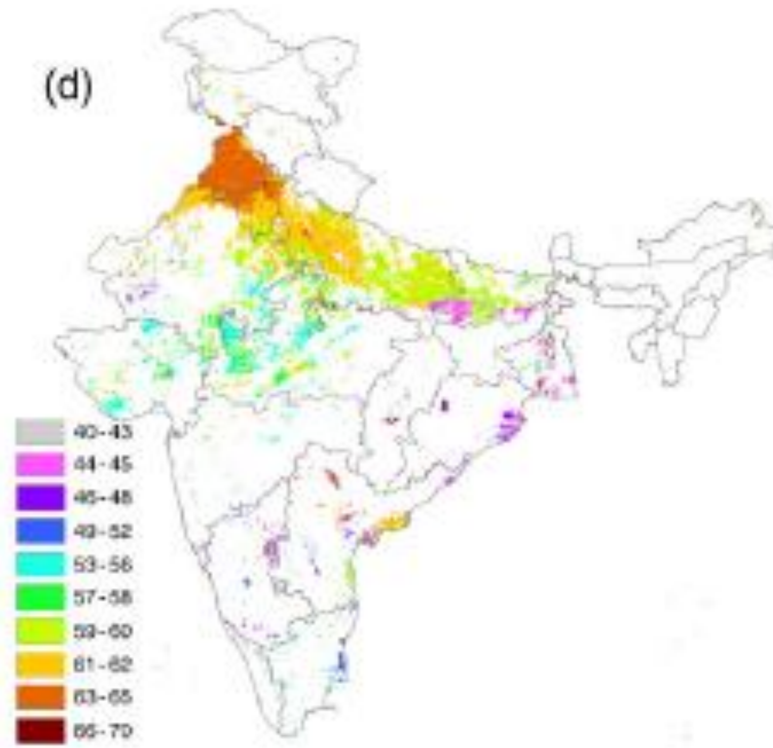

Second Growing season

Long term phenology change using GIMMS NDVI data

Climate Impact on Phenology

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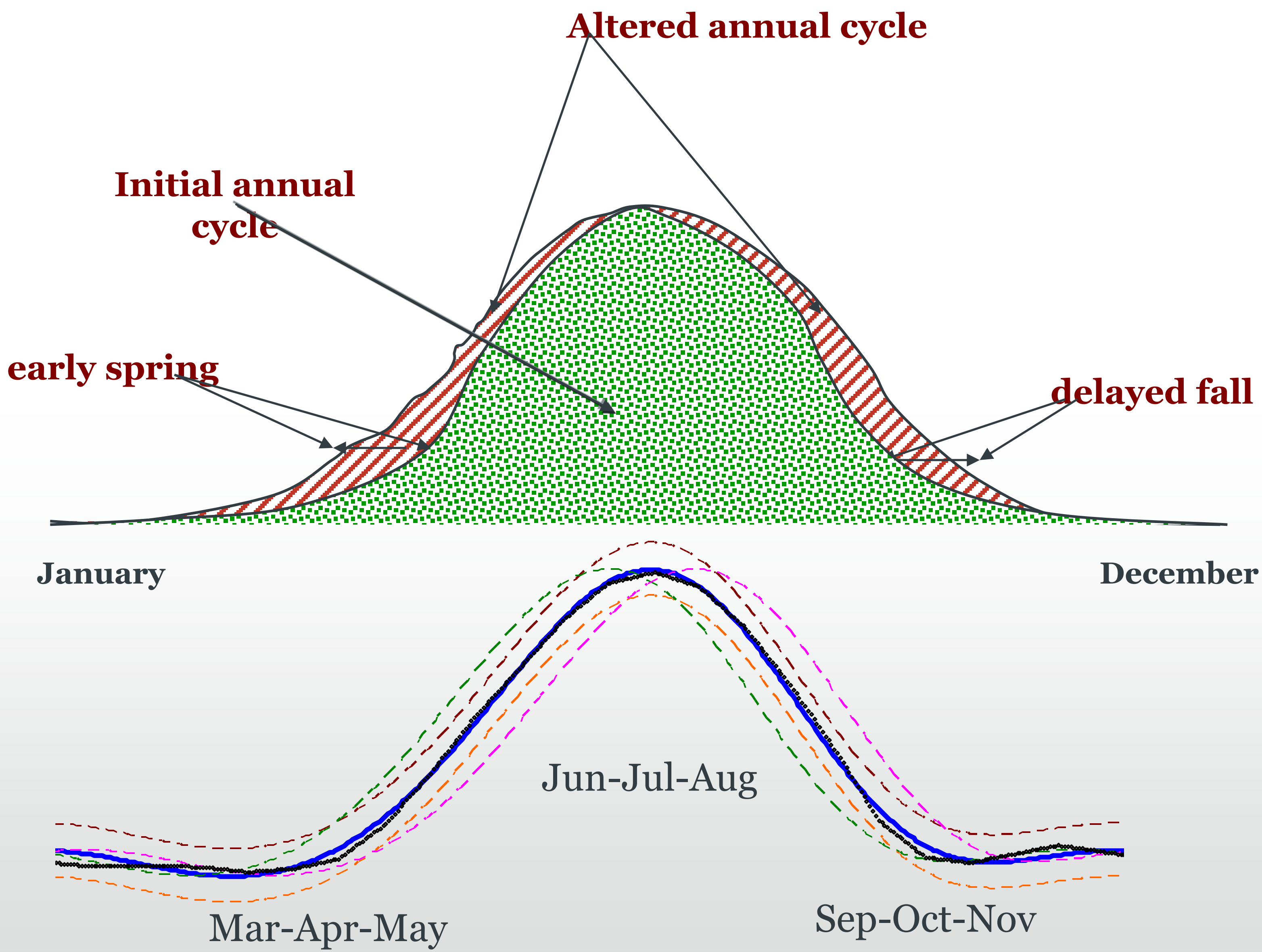
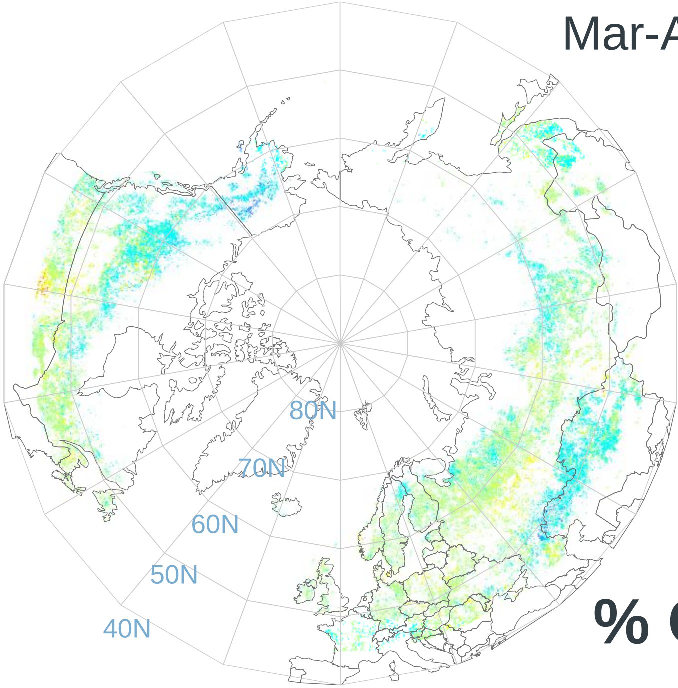
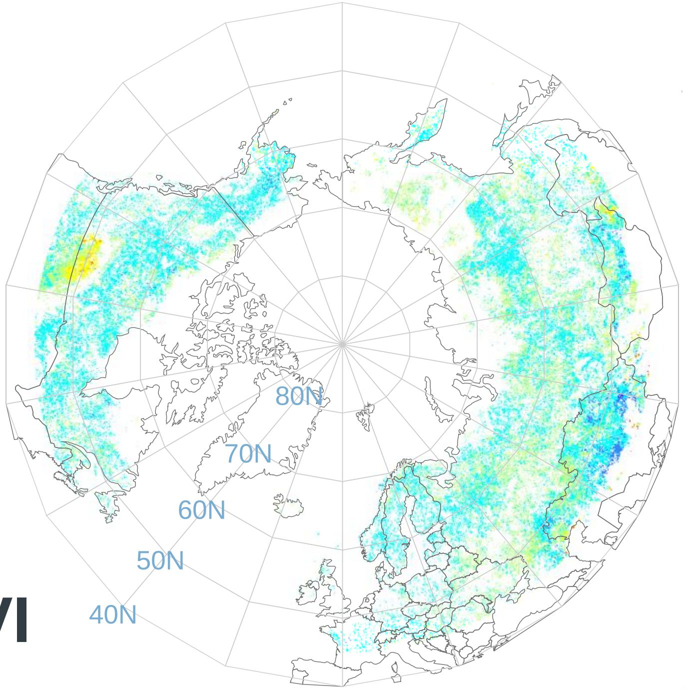


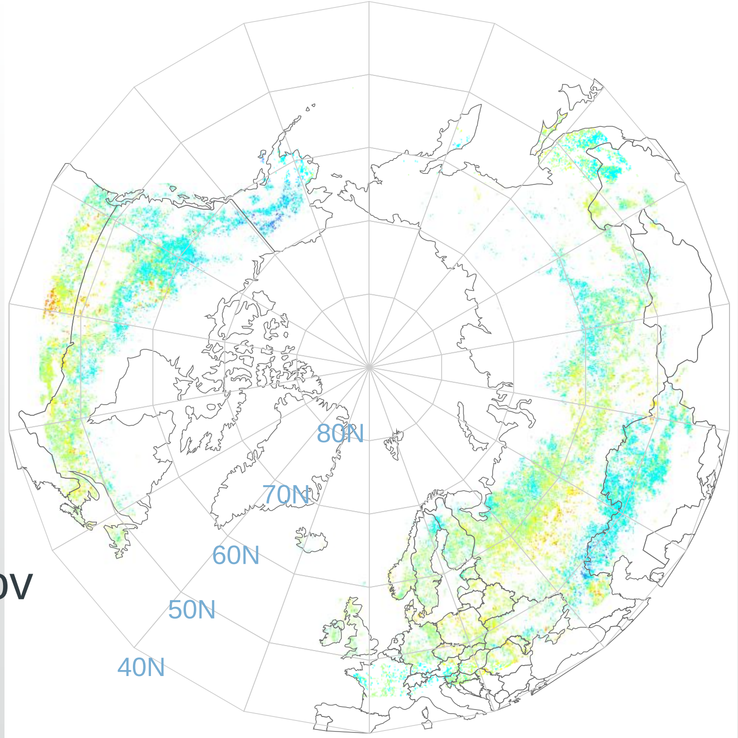
Mar-Apr-May



% Change in NDVI



Jun-Jul-Aug



Sep-Oct-Nov

Legend

- < -40%
- -40 to -20%
- -20 to 0%
- 0 to 20%
- 20 to 40%
- 40 to 60%
- > 60%

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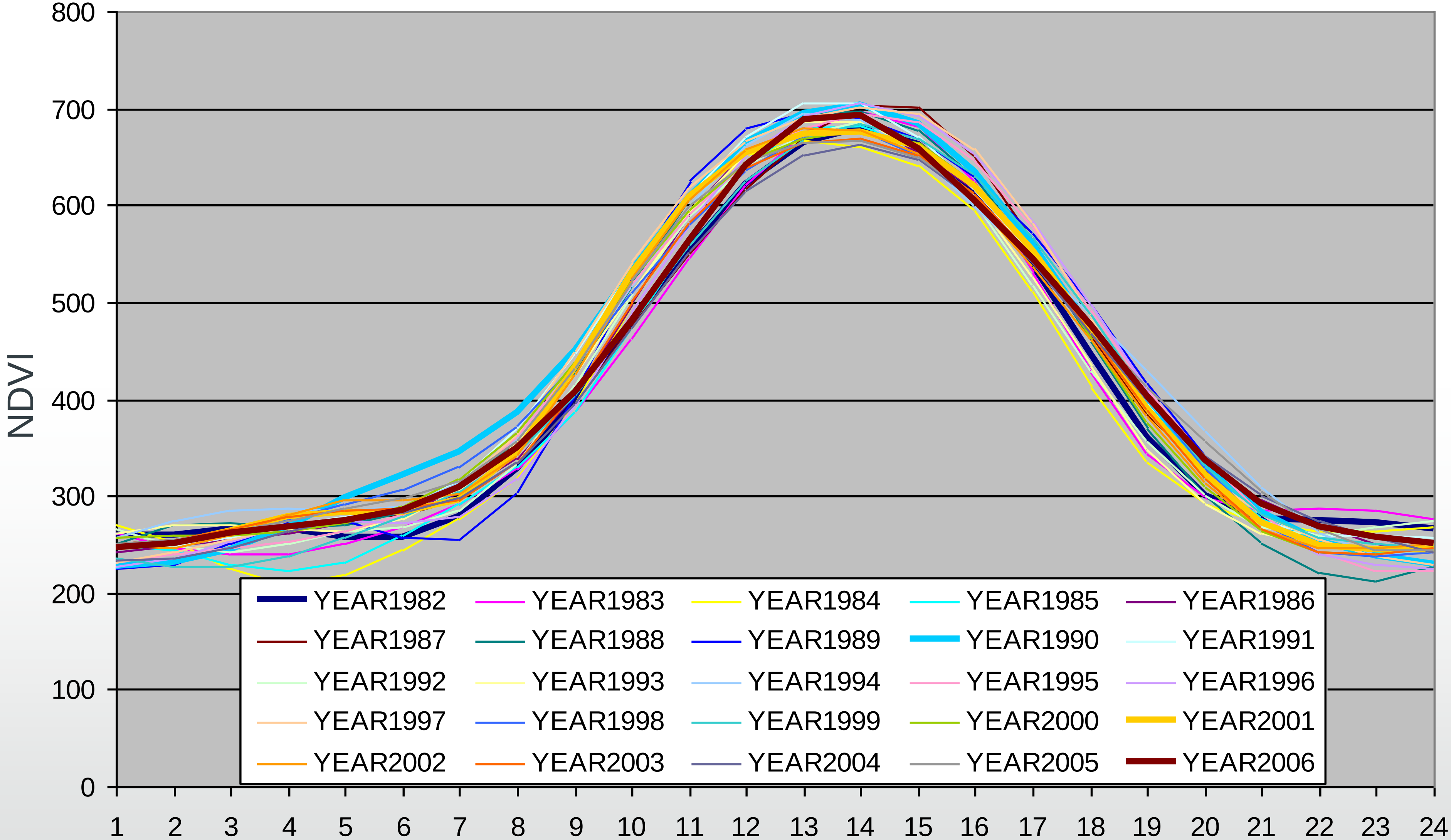
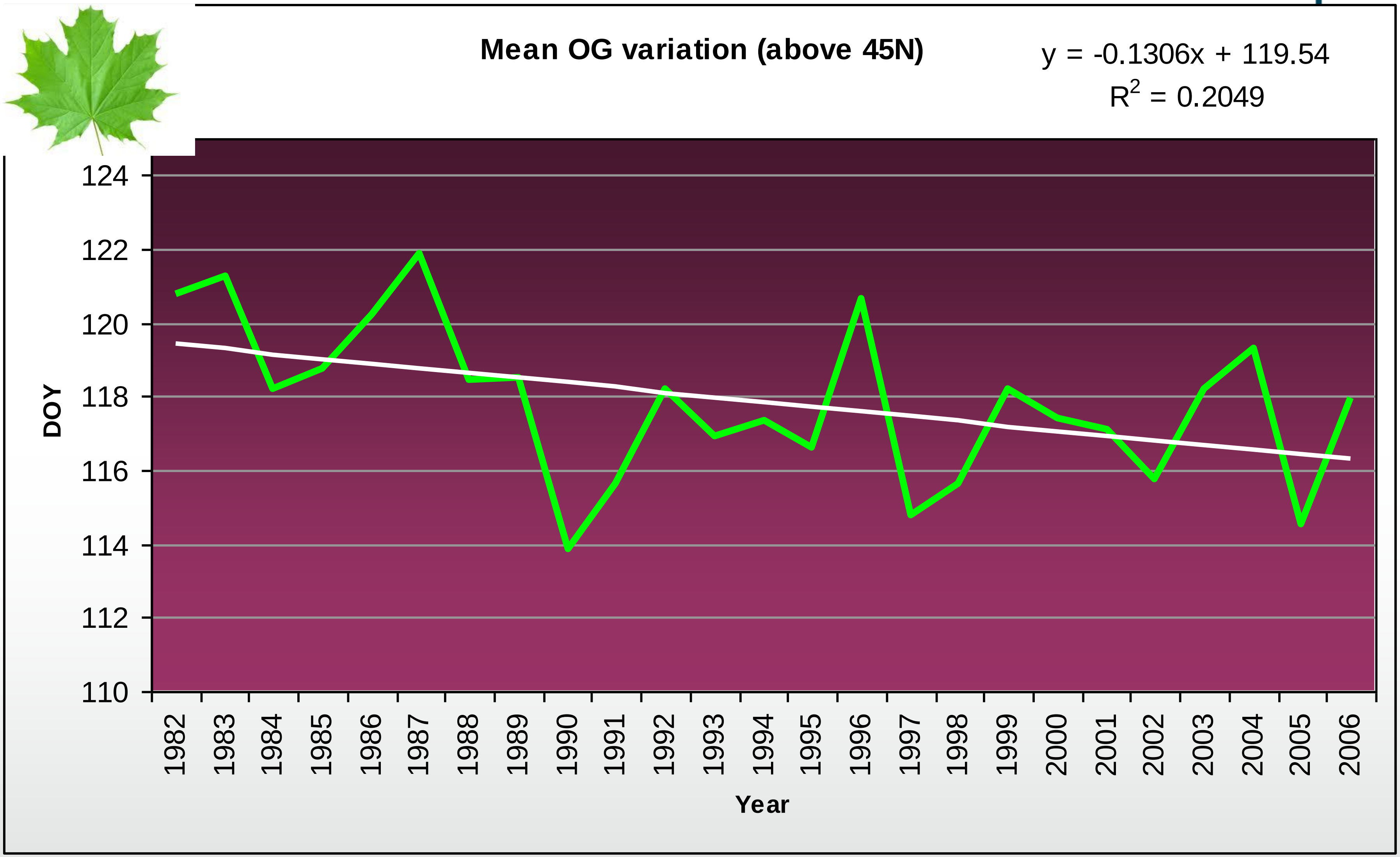
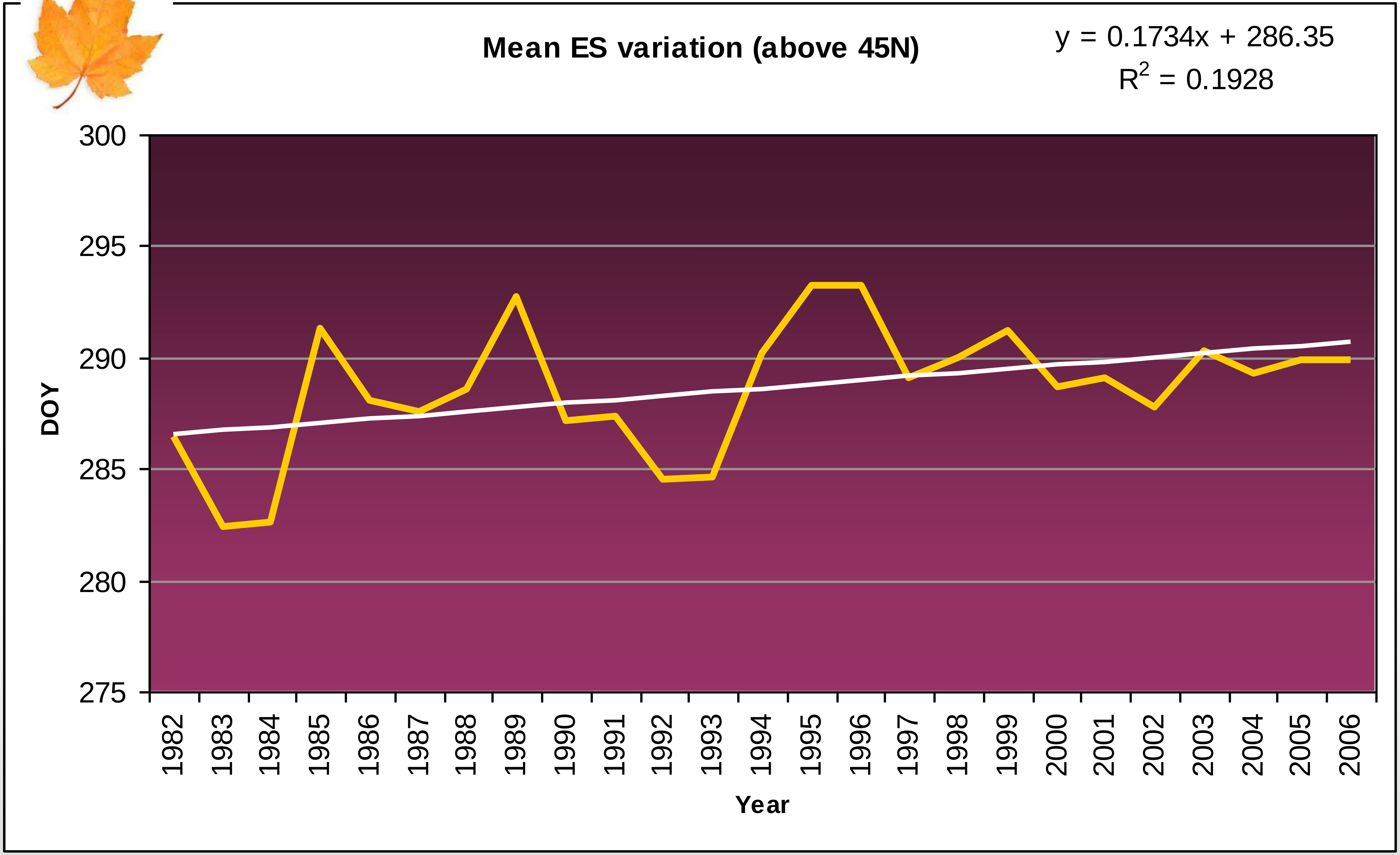
Fourier Smoothed Yearly NDVI variation




Mean OG variation (above 45N)
y = -0.1306x + 119.54
R2 = 0.2049
DOY
124
122
120
118
116
114
112
110
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Year



Mean ES variation (above 45N)
y = 0.1734x + 286.35
R2 = 0.1928
300
295
290
285
280
275
DOY
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
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2002
2003
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2005
2006
Year

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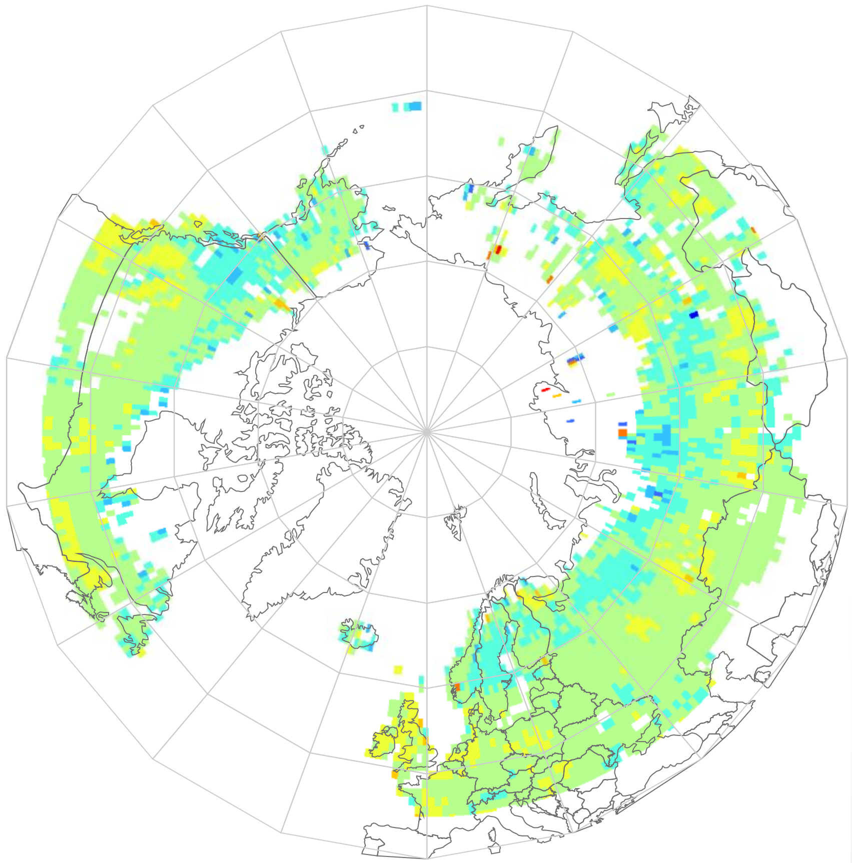
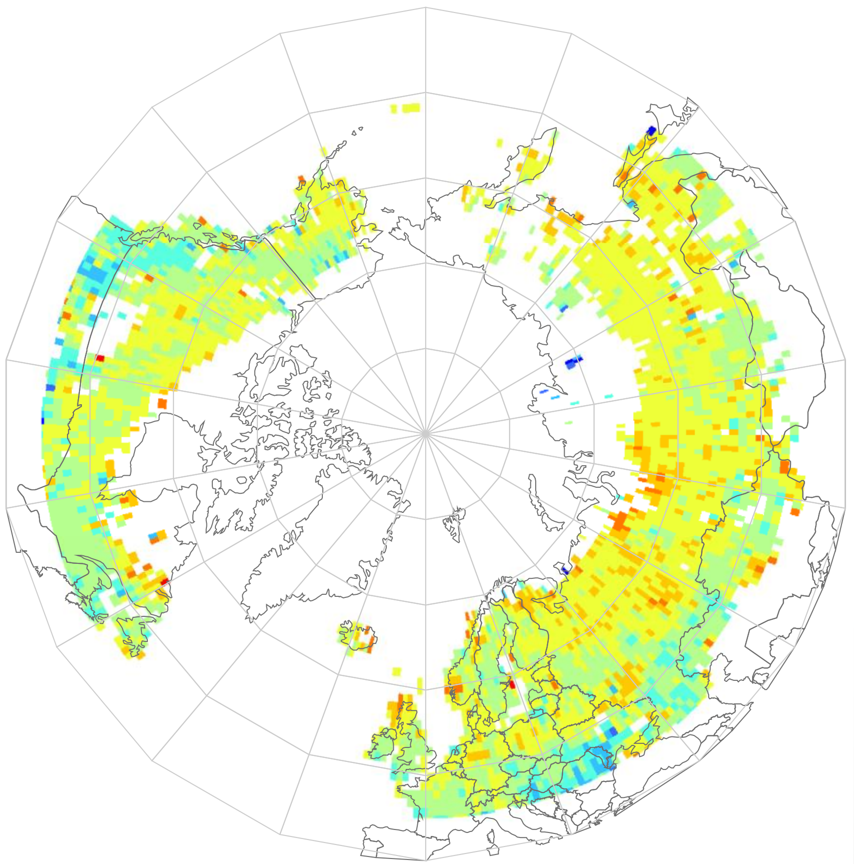
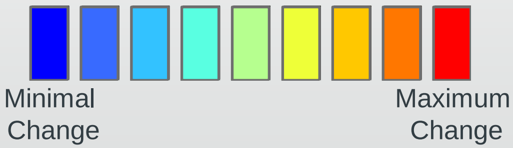


Onset of Greenness (OG)



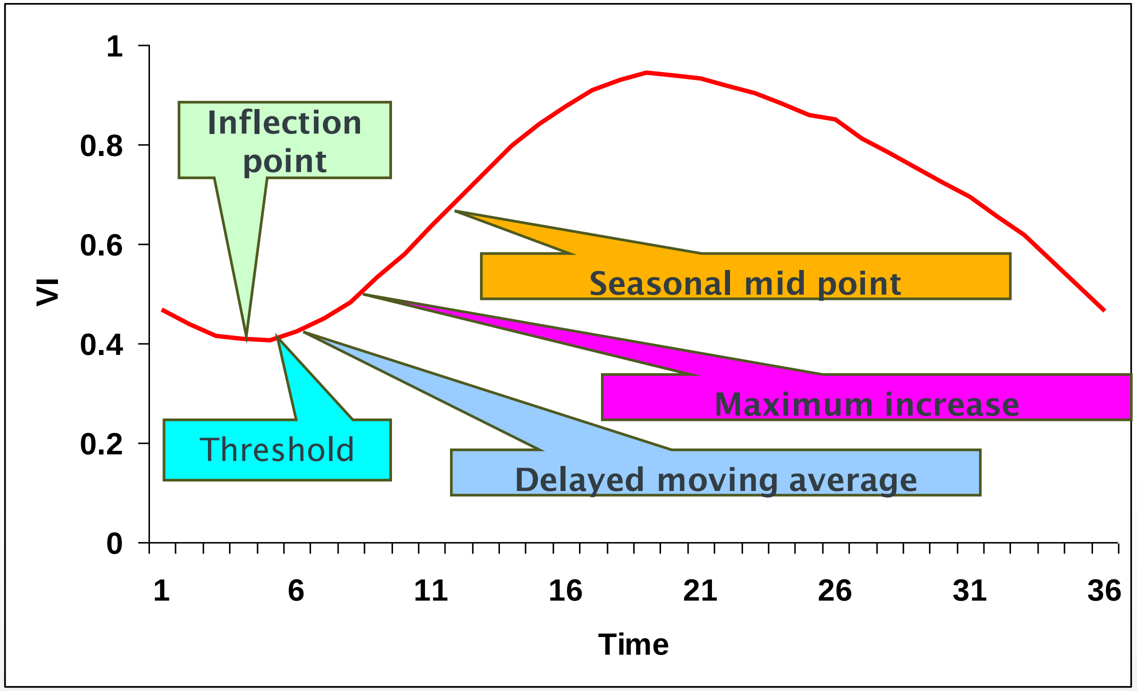
End of Senescence (ES)



Degree of Change in OG & ES

Phenology from Space: Challenge II

Inconsistency in Definition



What is start of season?

Aim:

- Independent of the study site and phenological pattern
- Can detect multiple annual cycles
- Cycles which spread across calendar years

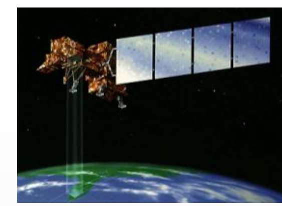
Phenology from Space: Challenge II Validation

Ground based

Citizen science, voluntary based, point-to pixel problem

Satellite based (!)

High spatial resolution data, scaling up, Data availability



Camera based

High spatial (mostly horizontal) and hyper temporal resolution , effect of understorey, dominate foreground

Validation

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GODDARD SPACE FLIGHT CENTER

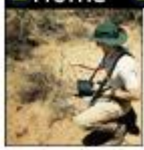
+ NASA Homepage

CEOS WORKING GROUP ON CALIBRATION & VALIDATION

Committee on Earth Observation Satellites

Land Product Validation Subgroup

Home Landcover Biophysical Surface Rad Fire/Burn LST/Emiss Phenology Soil Moisture



Annou

- Symposium -

Within the newly created working group structure of the LPV subgroup, a Phenology focus area was initiated in 2010, led by

Jeff Morisette of the UGSG Fort Collins Science Center
Jadu Dash of the University of Southampton

Phenology Focus Area Objectives

The newly formed Phenology Focus Group is currently in the process of developing a plan on how to effectively use ground- to airborne-level phenolocial measurements to validate satellite-based phenology products. This plan will involve an internationally-coordinated remote sensing phenology validation and inter-comparison activity that was initiated at the LPV workshop held following the recent Phenology 2010 Conference at Trinity College in Dublin, Ireland.

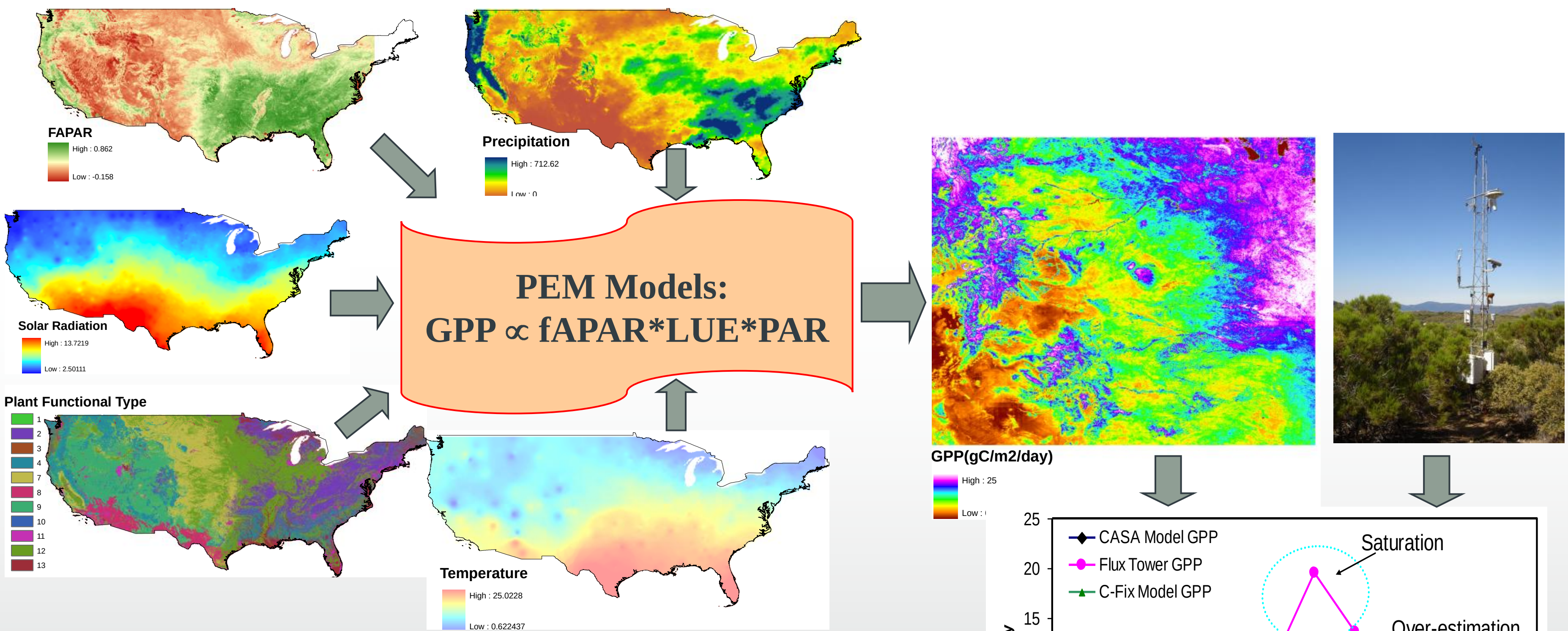
The Challenges

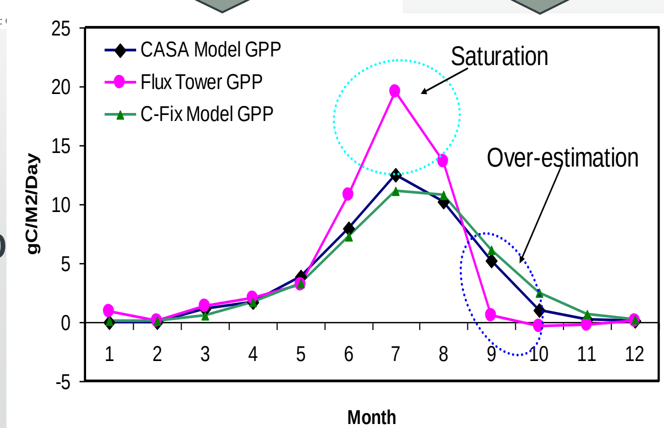
- Vegetation phenology involves an examination of both a physical signal as well a temporal component
- In situ phenology networks are often making observations that are not directly comparable to the aggregate vegetation response observed via satellite
- Developing a protocol to link ground phenological observations to satellite measurements

Possible Solutions

- Ground phenological observations (in situ phenological networks, such as Nature's Calendar and the USA National Phenology Network)
- PAR@METER network (F. Baret)
- Phenologial Eyes Network (S. Nagai)
- USA Phenocam Network (A. RIchardson)

Ecosystem productivity: Opportunity-III

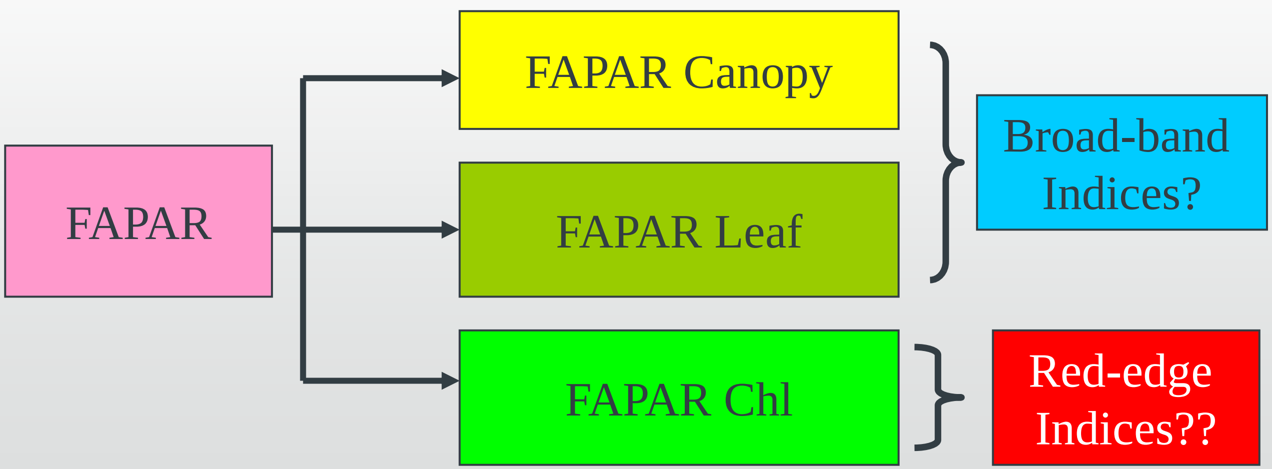




Ideally, the output of these model's should match-up to ground data from validation sites

Ecosystem productivity: Challenge-III

- One of the possible sources of uncertainties in the PEM models may be due to misrepresentation of FAPAR (an important input into the models)
- Current FAPAR products represent the whole canopy FAPAR
- Canopy composed of photosynthetic and non-photosynthetic components



Ecosystem productivity: Challenge-III

Old Paradigm but ignored!

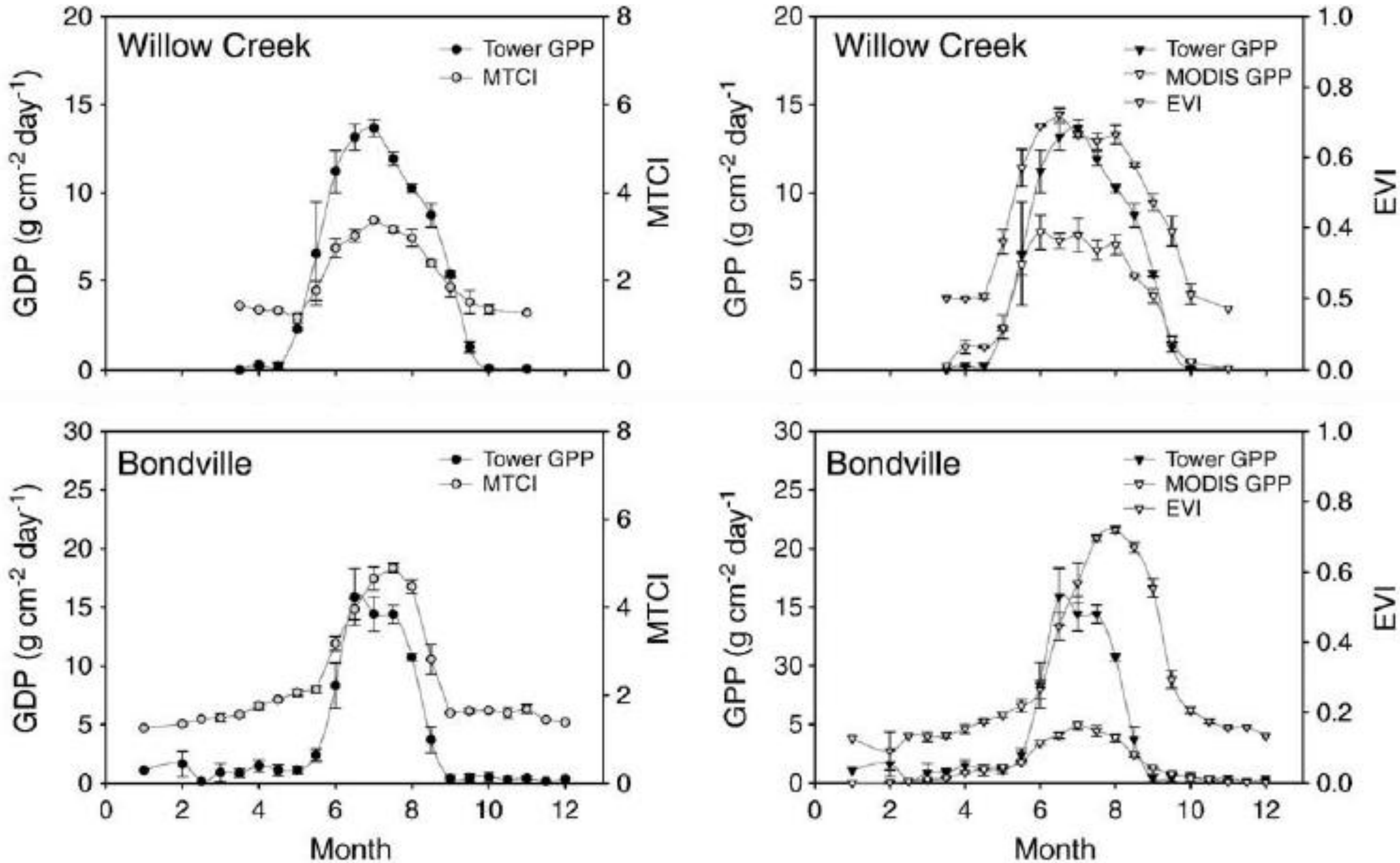
Canopy chlorophyll content is a very direct expression of the photosynthetic apparatus of a plant community and may be strongly related to **productivity and net photosynthesis** (Medina and Leith, 1964)

The potential of the MERIS Terrestrial **Chlorophyll** Index for **carbon flux** Estimation (Harris and Dash, 2010)

Remote estimation of **gross primary production** in maize and support for a new paradigm based on total **crop chlorophyll content** (Peng et al, 2011)

Ecosystem Productivity

Temporal variation



Ecosystem Productivity

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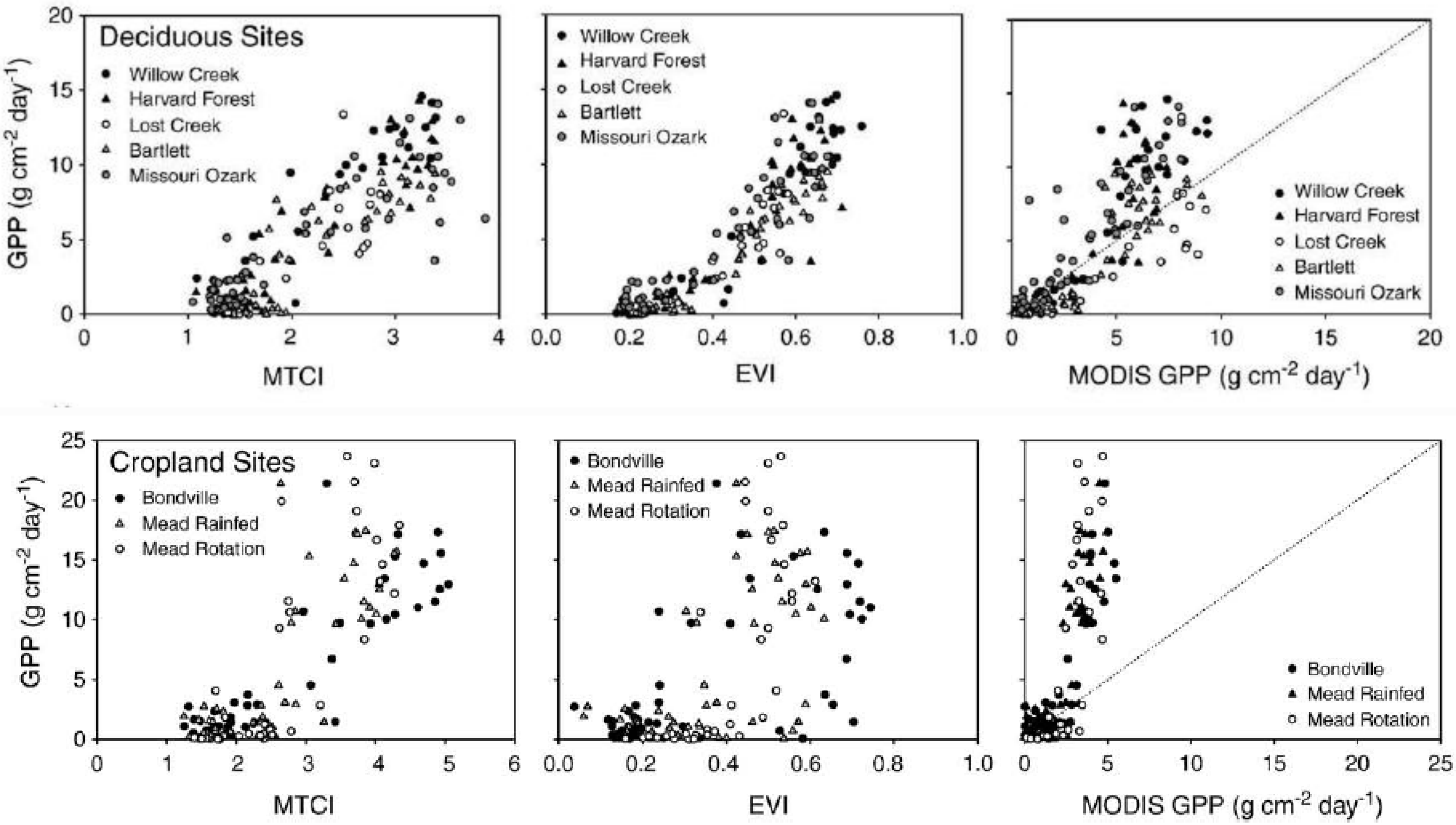

Conclusions

- ❖ MERIS MTCI is only product available operationally to estimate canopy chlorophyll content globally
- ❖ More that 8 years of global data now available
- ❖ MTCI has a strong phonological signal and links well with data from Flux tower and has potential for estimation of global GPP.
- ❖ Can be used as a complementary to other biophysical products for global scale application

Thank you