Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) product from Landsat 5 and 7

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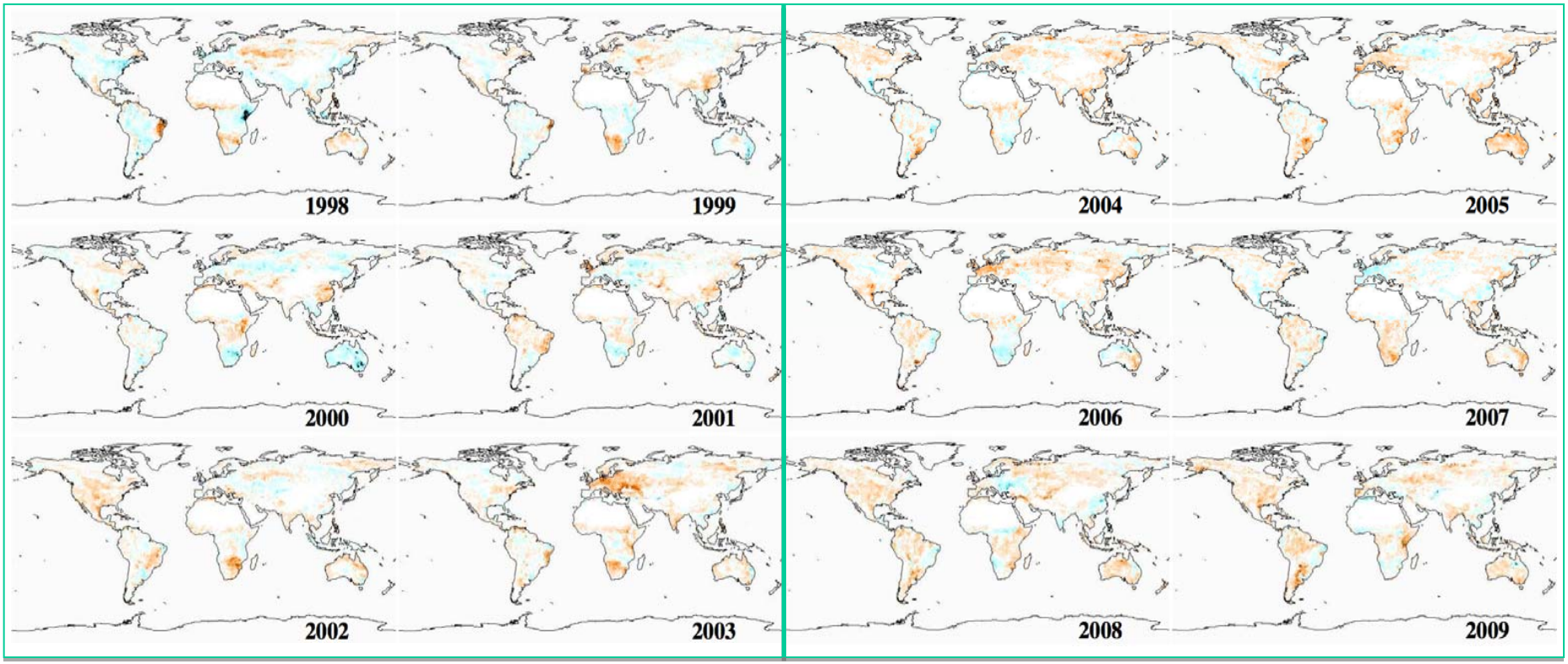
Table 1: Essential Climate Variables that are both currently feasible for global implementation and have a high impact on UNFCCC requirements

Domain	Essential Climate Variables	
Atmospheric (over land, sea and ice)	**Surface**[7]**:**	Air temperature, Wind speed and direction, Water vapour, Pressure, Precipitation, Surface radiation budget.
	Upper-air[8]**:**	Temperature, Wind speed and direction, Water vapour, Cloud properties, Earth radiation budget (including solar irradiance).
	Composition:	Carbon dioxide, Methane, and other long-lived greenhouse gases[9], Ozone and Aerosol, supported by their precursors[10]
Oceanic	**Surface**[11]**:**	Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity.
	Sub-surface:	Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers, Phytoplankton.
Terrestrial	River discharge, Water use, Ground water, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, Soil moisture.	

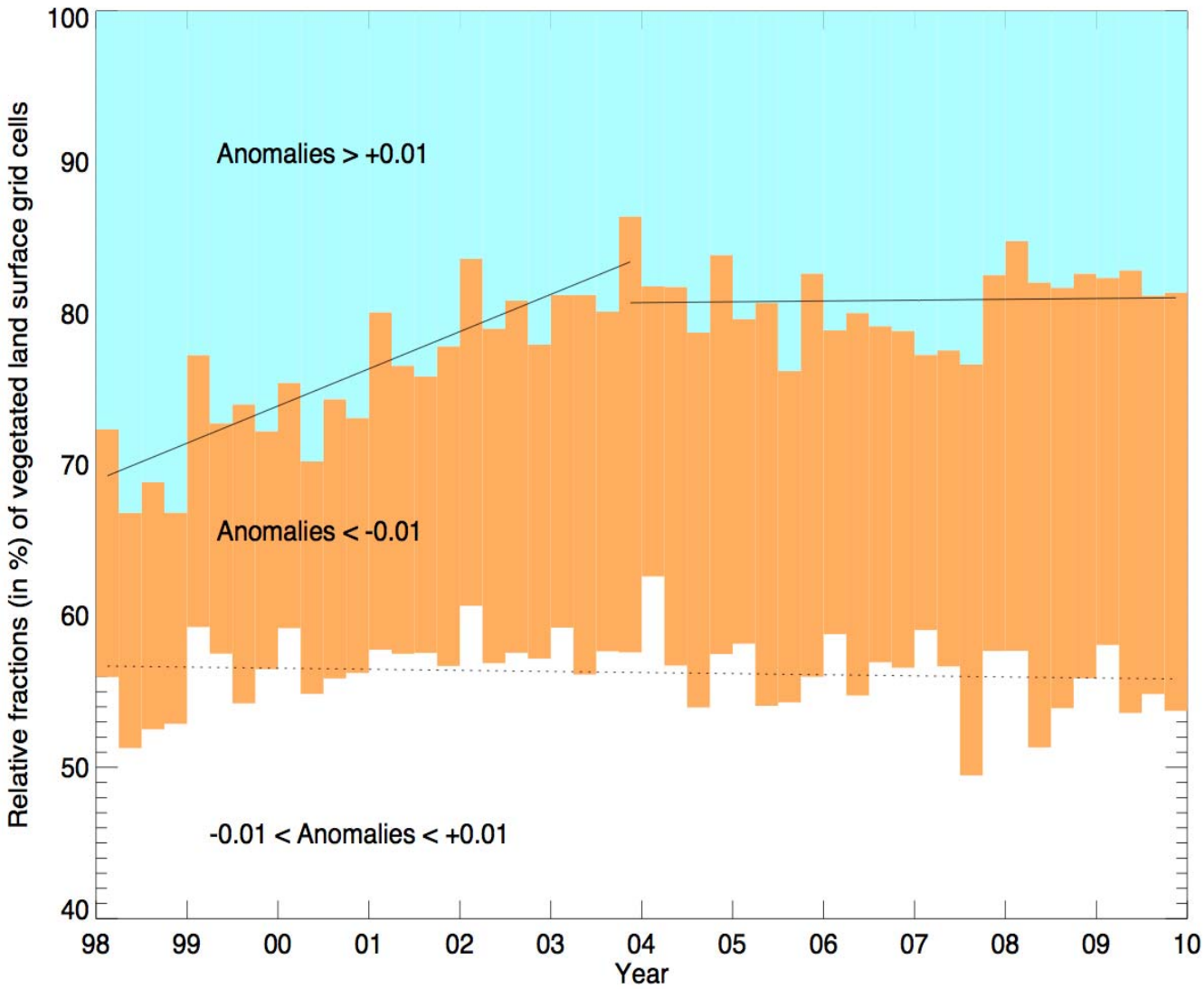
Satellite Derived FAPAR Anomalies

Anomalies 1998 - 2009 - Base period 1998 - 2010



Gobron et al. 2010 GRL http://www.agu.org/journals/pip/gl/2010GL043870-pip.pdf

Relative fraction of land surface showing fAPAR anomaly



Gobron et al. 2010 GRL http://www.agu.org/journals/pip/gl/2010GL043870-pip.pdf

Main FAPAR product providers.

Projects/Institution	Input data	Output product	Retrieval Method	References
JRC-FAPAR **ESA MERIS**	Top of Atmosphere (TOA) BRFs in blue, red and near-infrared bands	**Instantaneous green FAPAR based on direct incoming radiation**	Optimization Formulae based on Radiative Transfer Models	Gobron et al (2000, 2006, 2008)
NASA MODIS LAI/FPAR	Surface reflectance in 7 spectral bands and land cover map.	FAPAR with direct and diffuse incoming radiation	Inversion of 3D Model versus land cover type with backup solution based on NDVI relationship)	Knyazikhin et al. (1998b)
NASA MISR LAI/FPAR	Surface products BHR, DHR & BRF in blue, green, red and near-infrared bands + CART	FAPAR with direct and diffuse incoming radiation.	Inversion of 3D Model versus land cover type with backup solution based on NDVI relationship)	Knyazikhin et al. (1998a)
GLOBCARBON	Surface reflectance red, near infrared, and shortwave infrared	Instantaneous FAPAR (Black leaves)	Parametric relation with LAI as function as Land cover type.	Plummer et al. (2006)
CYCLOPES	Surface reflectance in the blue, red, NIR and SWIR bands	FAPAR at 10:00 solar local time	Neural network	Baret et al (2007)
LANDSAF	Visible and Near-Infrared bands	FAPAR	Parametric relation	Roujean and Breon (1995)
JRC-TIP	Broadband Surface albedo in visible and near-infrared bands.	FAPAR & Green FAPAR for direct & diffuse incoming radiation	Inversion of two-stream model using the Adjoint and Hessian codes of a cost function.	Pinty et al. (2007)

N. Gobron & M. M. Verstraete (2009) FAPAR: assessment report on available methodological standards and guides, GTOS-65

Green FAPAR

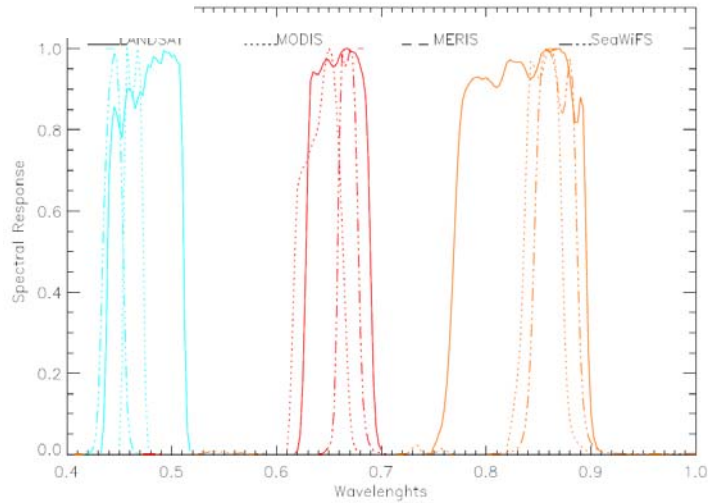
Leaf-only FAPAR refers to the fraction of PAR radiation absorbed by live leaves, i.e., contributing to the photosynthetic activity within leaf cells

This quantity is lower than ‘total’ FAPAR because it does not include PAR absorption by the supporting woody or senescent material

The retrieval method assumes that leaves are alive and photosynthesizing, hence the name ‘green’ FAPAR

Scheme for the algorithm optimization

Sensor Spectral response for blue, red and near-infrared bands



Radiation Transfer Models

BRF TOA | BRF TOC | FAPAR

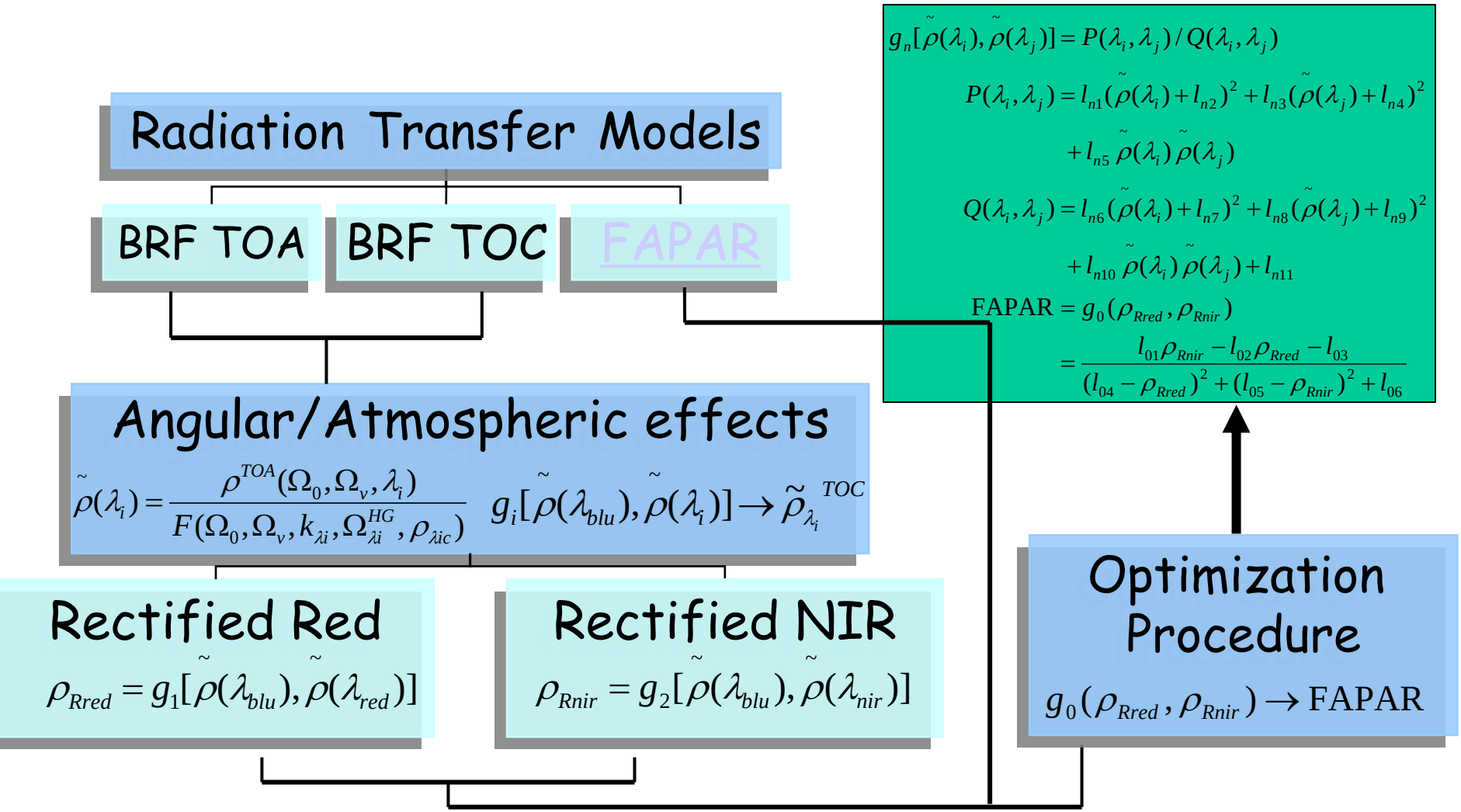
Semi-discrete (Gobron et al., 1997)

6S (Vermote et al., 1997)

Vector Version of 6S (Kotchenova SY, 2006, 2007)

Gobron, N., B. Pinty, M. M. Verstraete & J.-L. Widlowski (2000) 'Advanced Vegetation Indices Optimized for Up-Coming Sensors: Design, Performance and Applications', *IEEE Transactions on Geoscience and Remote Sensing*, 38, 2489-2505.

Scheme for the algorithm optimization



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Processing chain

Inputs: DN of B10 B30 B40 & MTL files + Metadata tool

Radiances are computed:
R(λ) = gain(λ) DN + offset(λ)
& top of atmosphere reflectance

$$\rho(\lambda) = \frac{\pi \, \mathrm{R}(\lambda) dsol^2}{E_0(\lambda)\cos(\theta_0)}$$

Gain, Offset
Sun elevation
Sun view
Center latitude
Viewing zenith angles

Outputs:
ρ(B10),ρ(B30),ρ(B40)
SZA,VZA,RAA

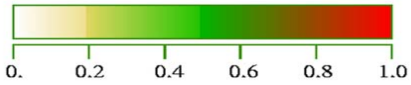
$$g_n[\tilde{\rho}(\lambda_i), \tilde{\rho}(\lambda_j)] = P(\lambda_i, \lambda_j) / Q(\lambda_i, \lambda_j)$$

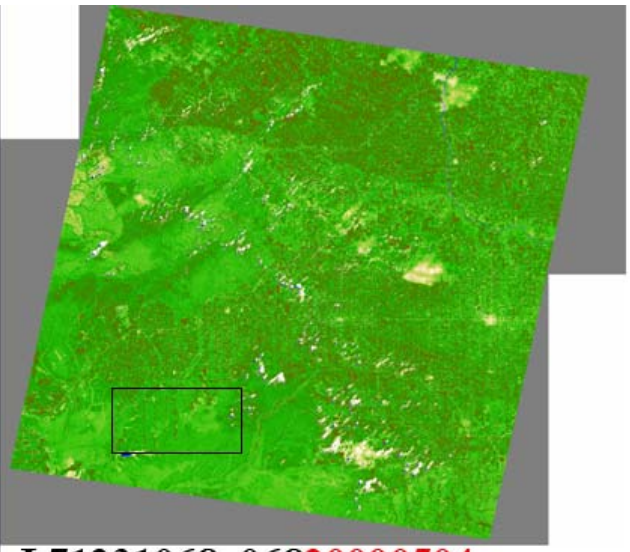
$$P(\lambda_i, \lambda_j) = l_{n1}(\tilde{\rho}(\lambda_i) + l_{n2})^2 + l_{n3}(\tilde{\rho}(\lambda_j) + l_{n4})^2 + l_{n5}\,\tilde{\rho}(\lambda_i)\,\tilde{\rho}(\lambda_j)$$

$$Q(\lambda_i, \lambda_j) = l_{n6}(\tilde{\rho}(\lambda_i) + l_{n7})^2 + l_{n8}(\tilde{\rho}(\lambda_j) + l_{n9})^2 + l_{n10}\,\tilde{\rho}(\lambda_i)\,\tilde{\rho}(\lambda_j) + l_{n11}$$

$$\mathrm{FAPAR} = g_0(\rho_{Rred}, \rho_{Rnir}) = \frac{l_{01}\rho_{Rnir} - l_{02}\rho_{Rred} - l_{03}}{(l_{04} - \rho_{Rred})^2 + (l_{05} - \rho_{Rnir})^2 + l_{06}}$$

Results over Rondonia





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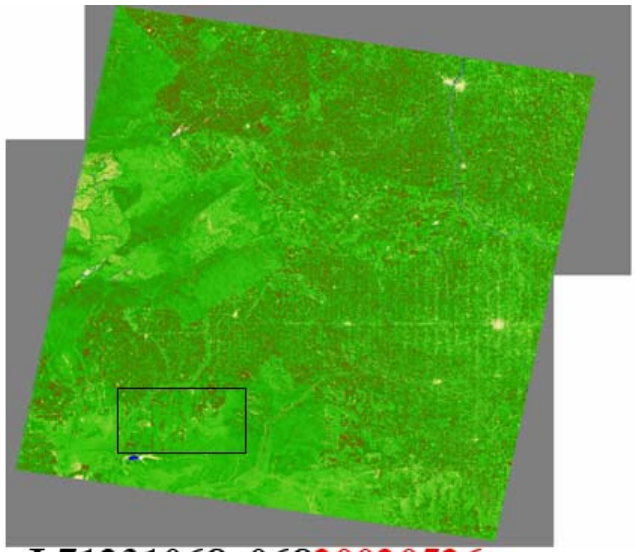

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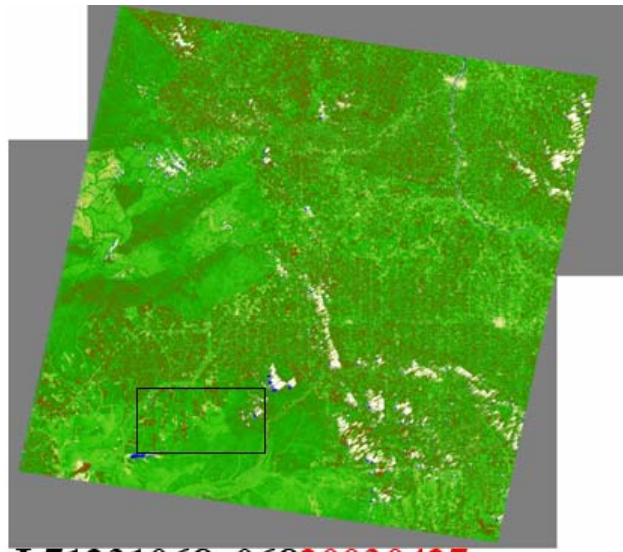

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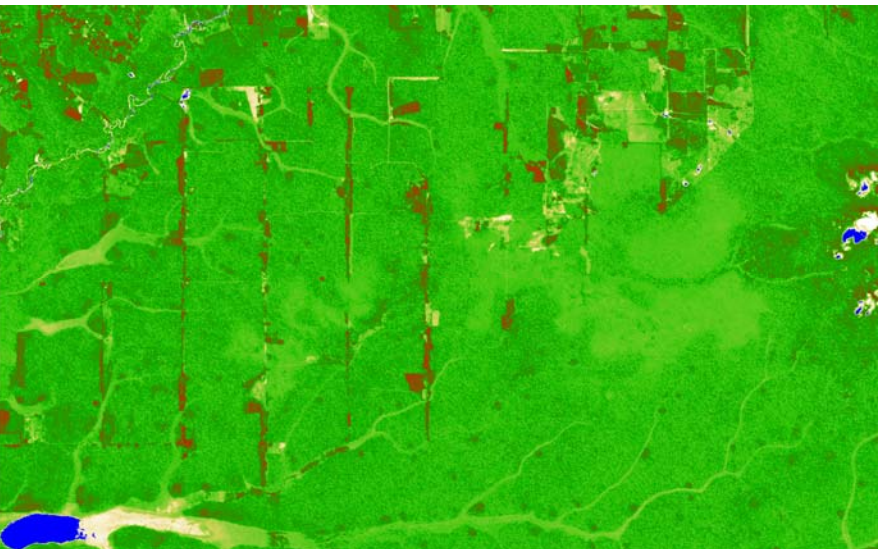
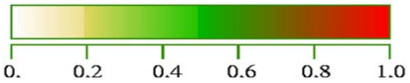
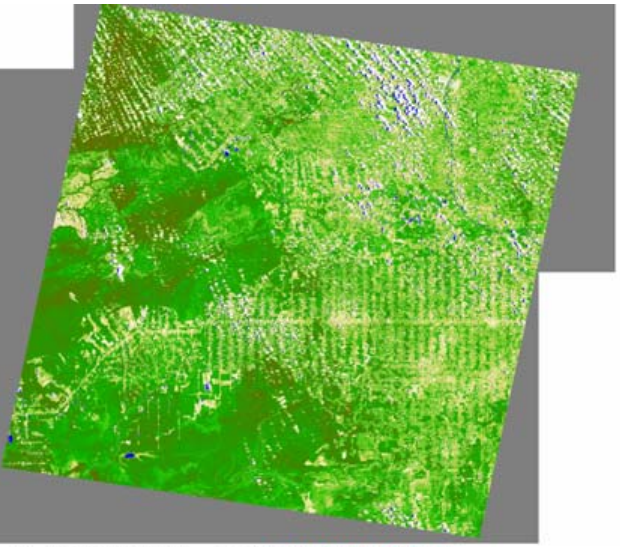


Test Using Landsat5 – algorithm requires further optimization





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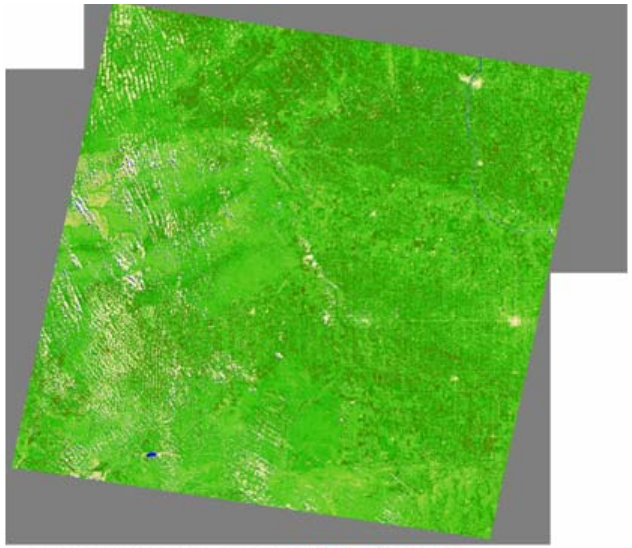

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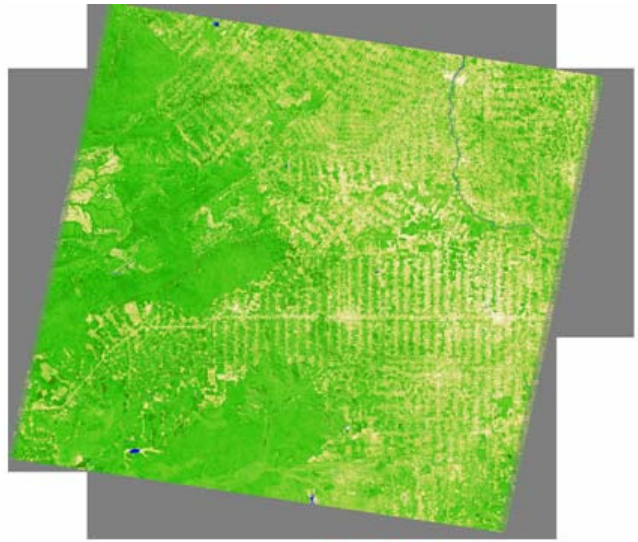

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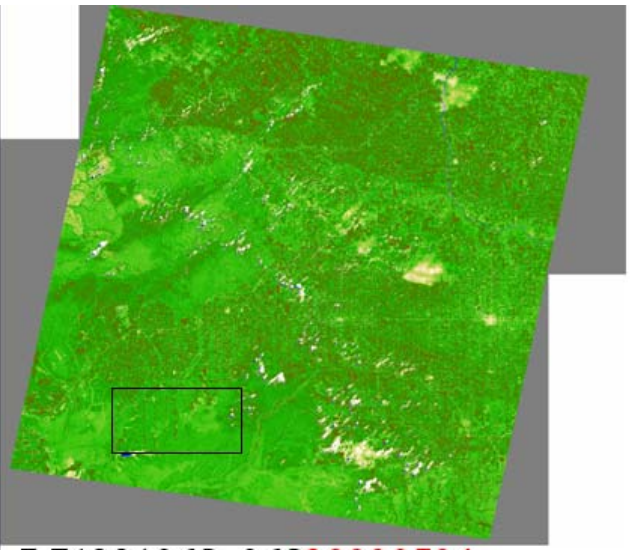

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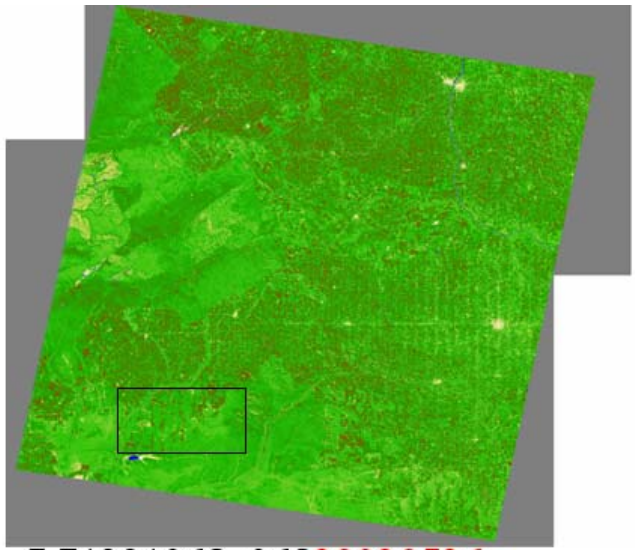

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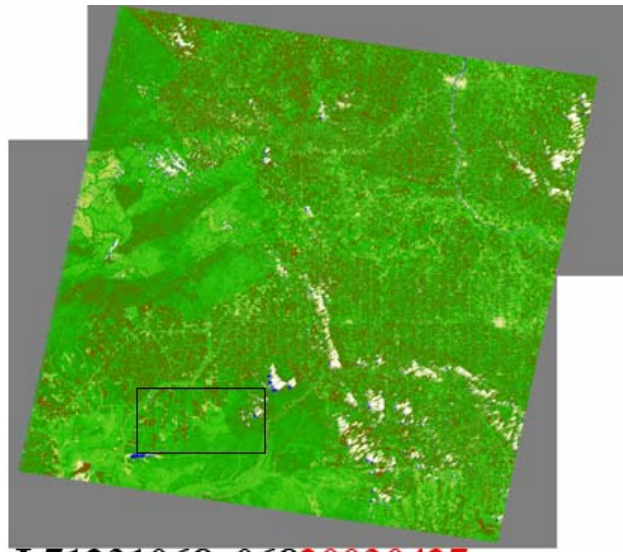

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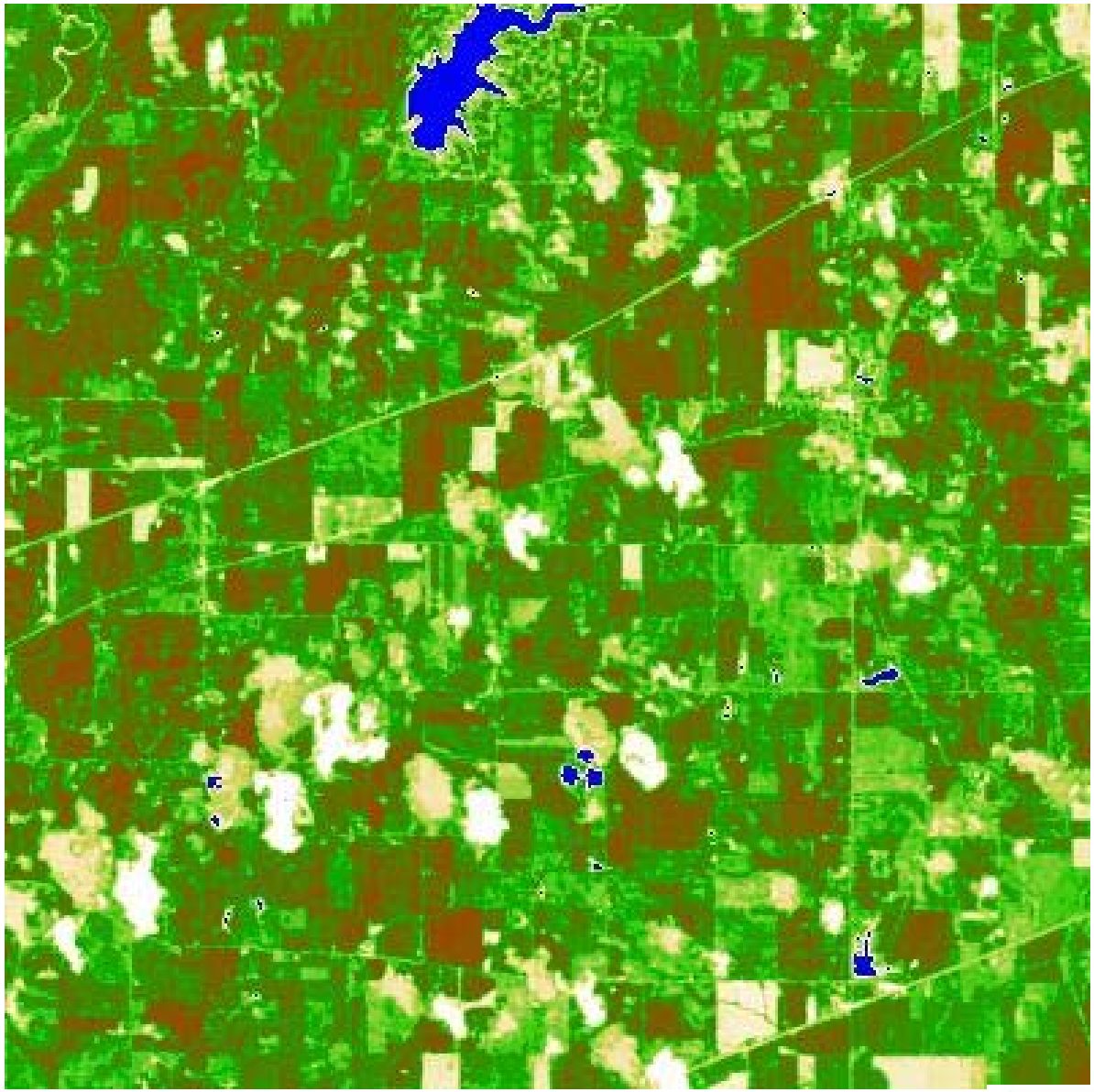
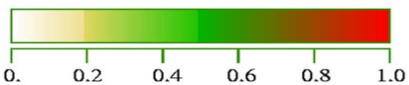
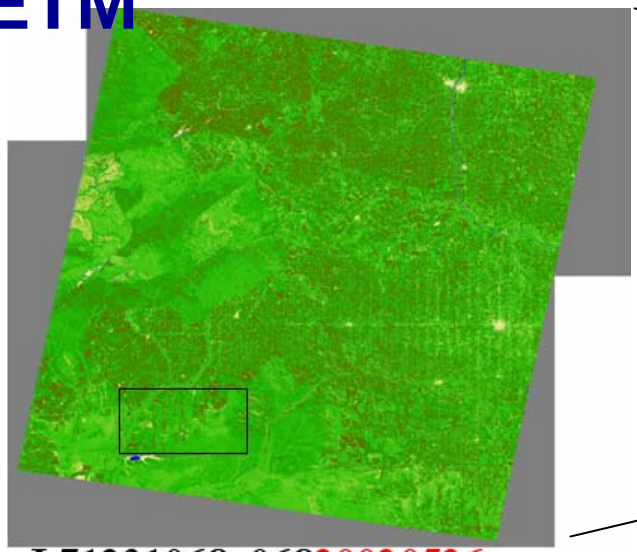
Cloud and shadow effects





Landscape heterogeneity

ETM



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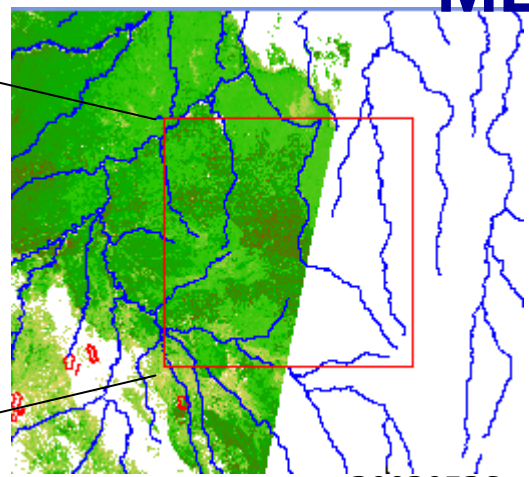
MERIS



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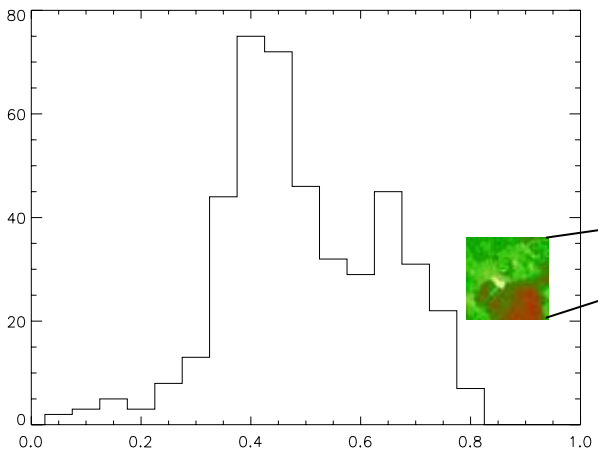

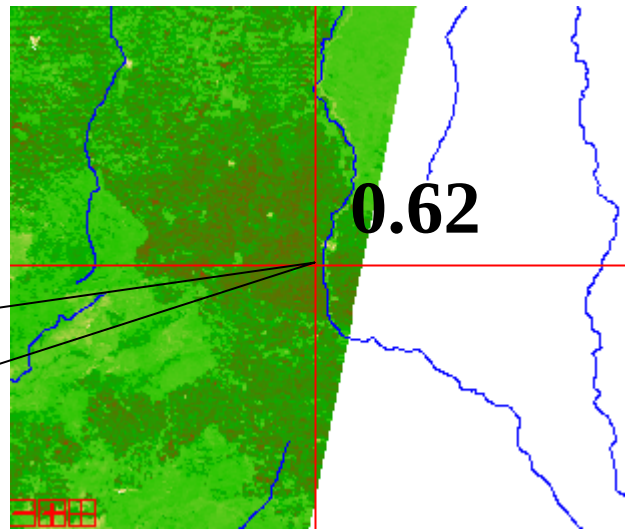

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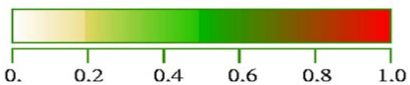
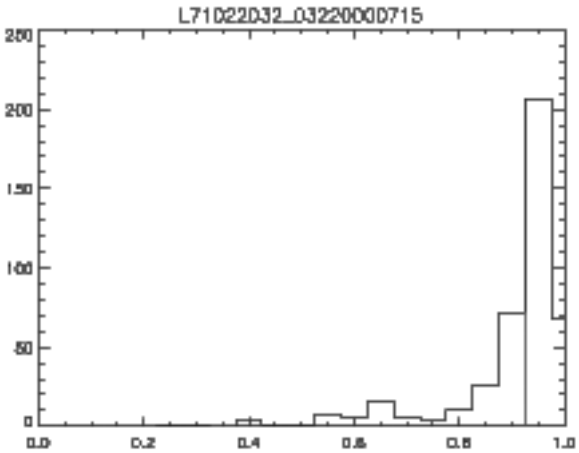
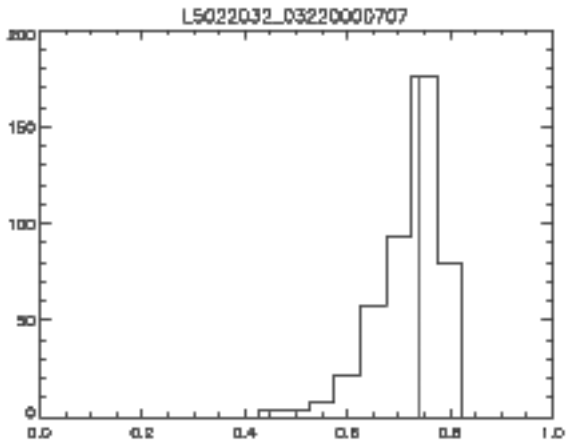
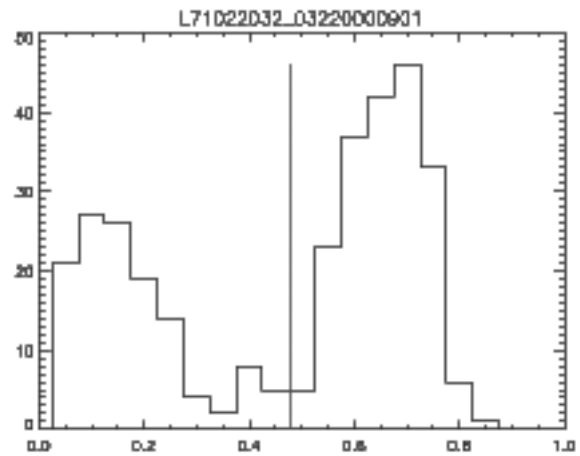
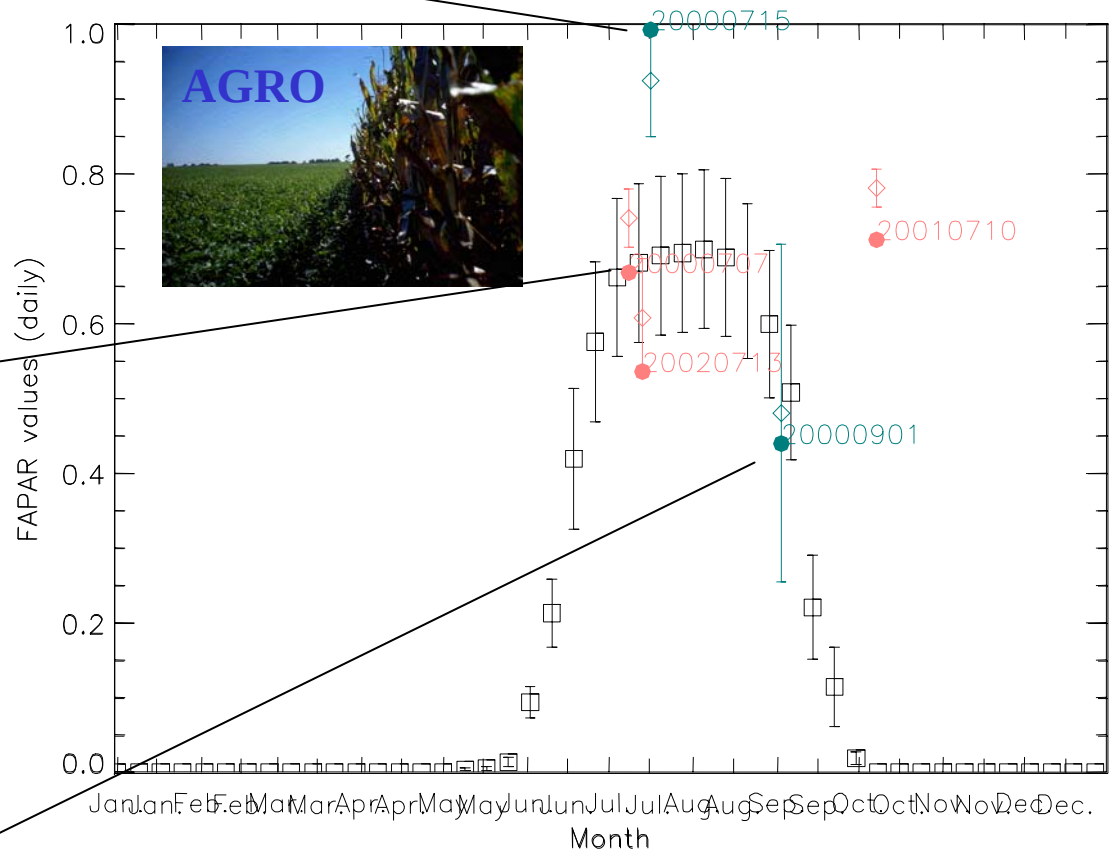


ETM FAPAR over AGRO site









Key messages

- Users are already out there
  - climate; weather; GPP/carbon; ecosystem stress, resilience and recovery
- Take care with the definition of the ECV
- Surface reflectance +angular info are essential inputs
- Cloud and cloud shadow are unsurprisingly a problem – especially shadow
- Scale issues are a challenge – but the finer resolution is a major advantage for some users
- Sentinel 3 and Sentinel 2 products are being developed
- *L5 and L7 data kindly provided by USGS, MERIS from ESA*