Retrieval of Land Surface Parameters from MODIS and MISR Albedo Products

B. Pinty[1], M. Clerici[1]

I. Andredakis [1], M. Vossbeck [3]T. Lavergne [2],
T. Kaminski [3] M. Taberner [1], N. Gobron[1]

1) EC-JRC, IES, Ispra, Italy
2) Norwegian Meteorological Institute, Blindern, Oslo
3) FastOpt, Hamburg, Germany

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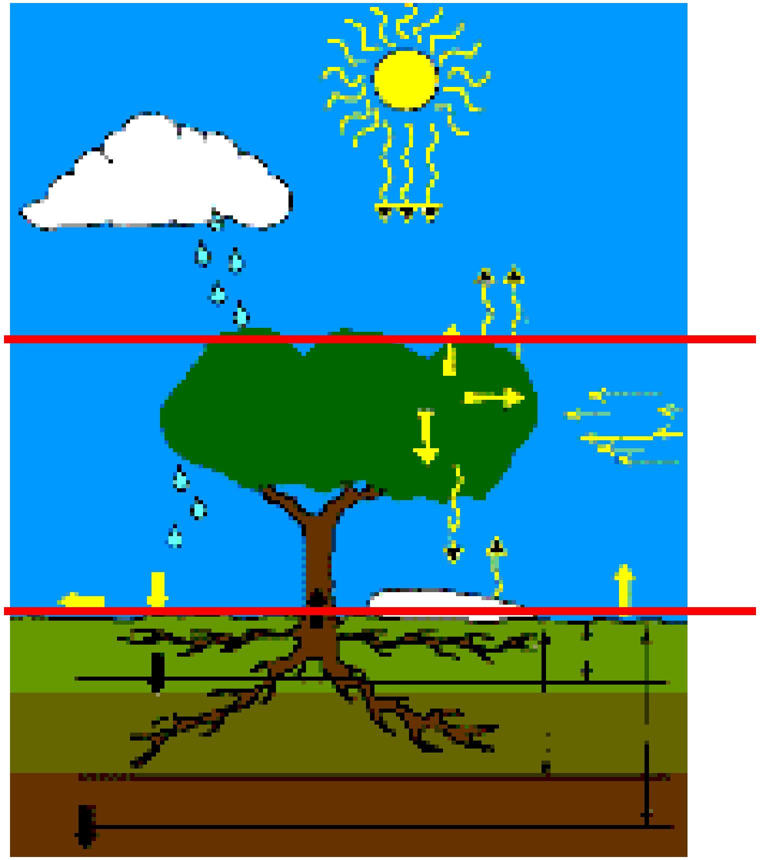
Energy partitioning between the vegetation and the soil layer



Ref: Bonan, G. B. (2002) Cambridge Univ. Press

- The **surface albedo** corresponds to the upper boundary condition of the vegetation plus soil RT and other problems

  Need to understand and represent the RT processes yielding the distribution of energy below that "surface", e.g., transmitted fluxes.

- The remaining energy in the soil "layer" is used to solve the heat conduction equation and soil hydrology, e.g., snow melting, evaporation.

- The energy left into the vegetation "layer" is used to drive the water, e.g., evapotranspiration, and the carbon cycle, e.g., NPP, NEP,..

Challenges for the Land community

- 4 identified ECVs namely Albedo, FAPAR, LAI and ultimately Land Cover are linked via radiation and phenological processes.
- Multiple datasets of these ECVs are available from different institutions.

The retrieval of these ECVs can be formulated in order to find solutions **optimizing all the available information** i.e., inferring statistically the state of the system

Challenges for the Land community

- 4 identified ECVs namely Albedo, FAPAR, LAI and ultimately Land Cover are linked via radiation and phenological processes:

  They MUST be retrieved consistently and then specified in the same manner in host models

- Multiple datasets of these ECVs are available from different institutions:

  They MUST be analyzed and exploited to establish a coherent set of information across platforms and institutions.

Retrievals of model Parameters for Land surface schemes

The inverse problem must be formulated in order to find solutions **optimizing all the available information** i.e., inferring statistically the state of the system

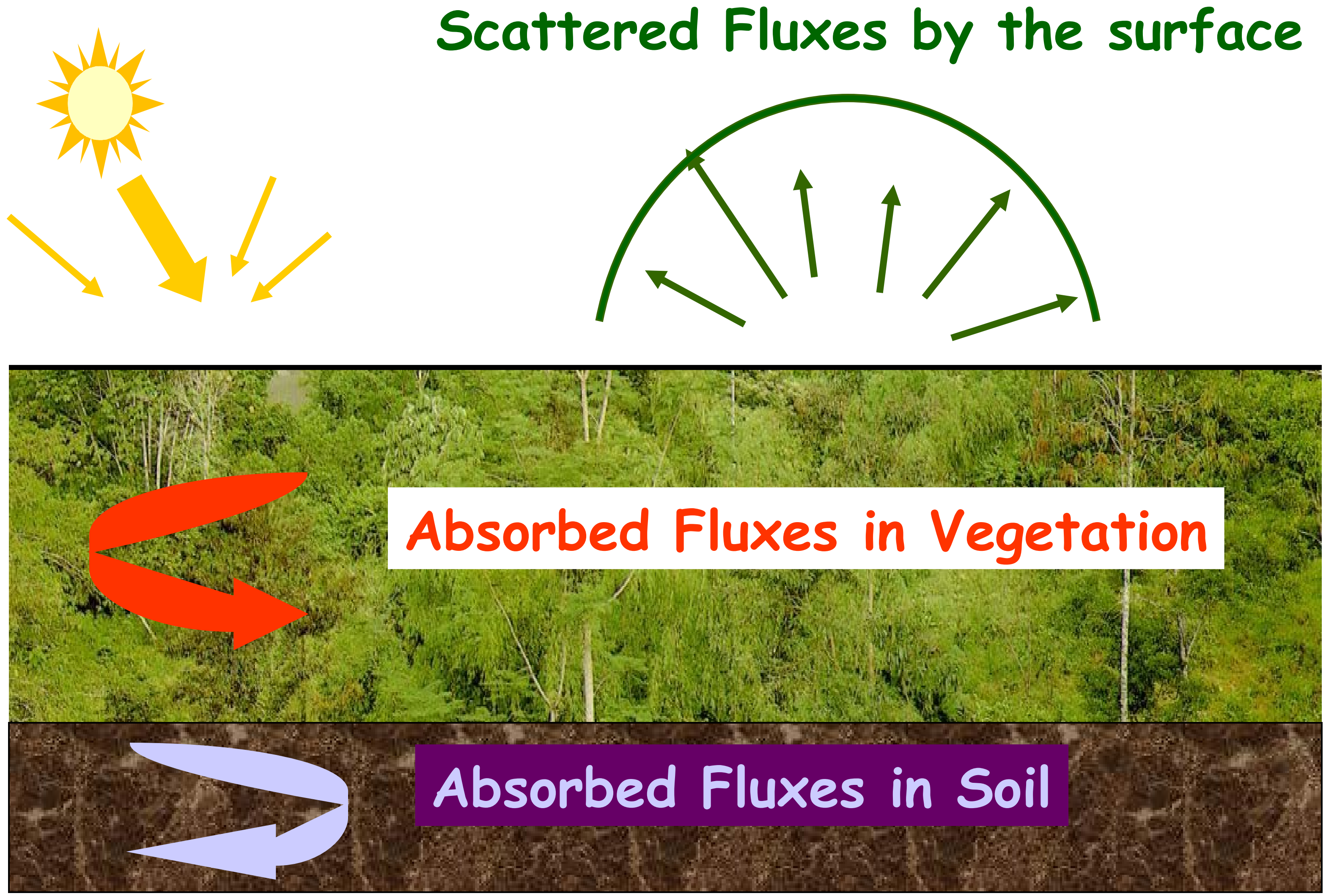
Towards an **integrated system** for the optimal use of remote sensing flux products

Towards an integrated system for the optimal use of remote sensing products

1- Develop a RT flux model to be used in forward/assimilation mode in SVAT modules of large scale models

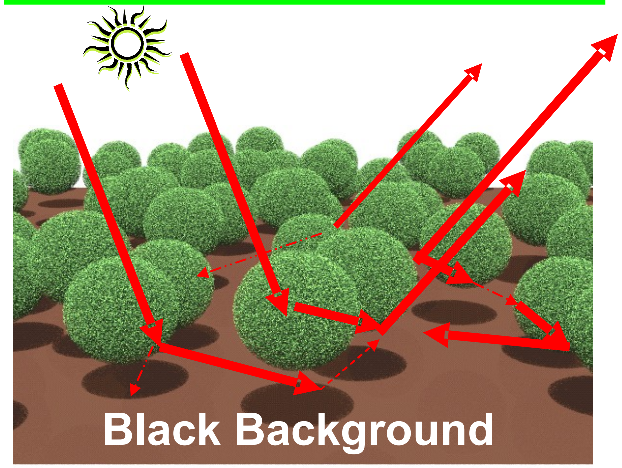
2- Infer the state variables of the RT flux model from satellite products, e.g., surface albedo

Two-stream model to redistribute Sun energy between the atmosphere and the biosphere



Design of the two-stream flux model

Amount of leaf material and leaf color

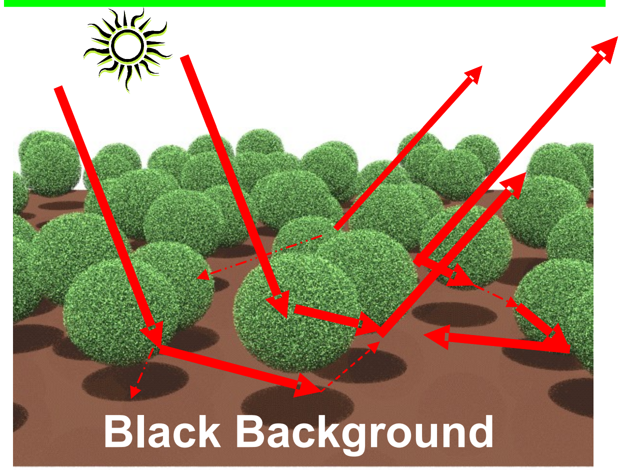


• Regulates the ***absorption*** processes associated with vegetation photosynthesis

Ref: Pinty et al. (2004) Journal Geophysical Research, doi:10,1029/2004JD005214

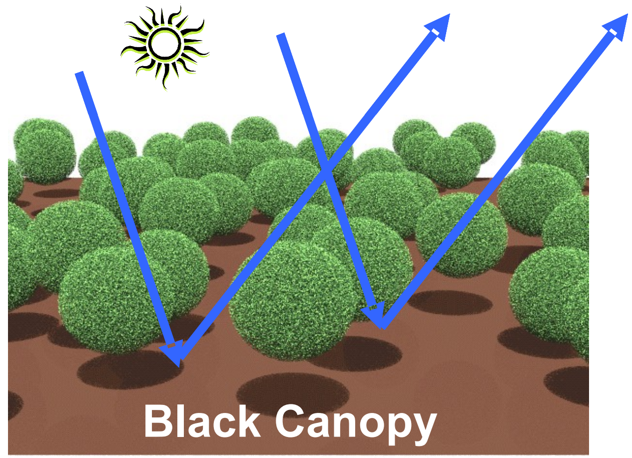
Design of the two-stream flux model

Amount of leaf material and leaf color



• Regulates the ***absorption*** processes associated with vegetation photosynthesis

Distribution of leaves and background albedo



• No absorption process by vegetation associated with this wavelength-independent contribution

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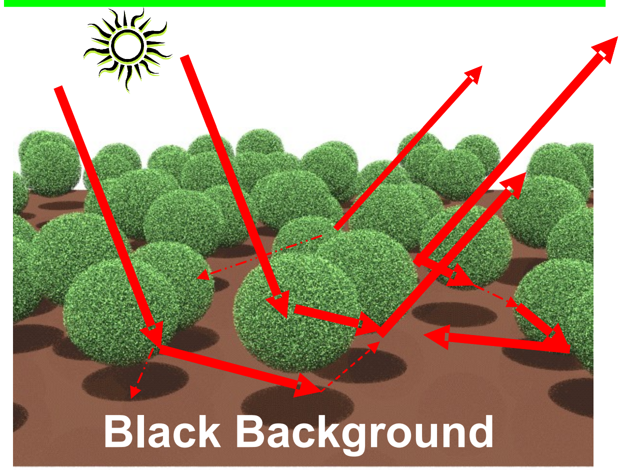
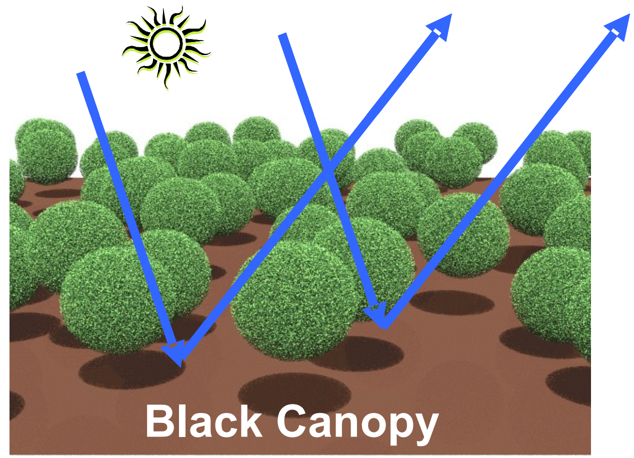
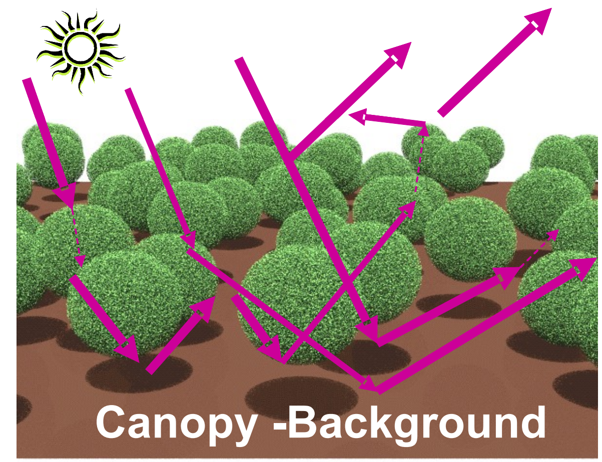
Distribution of leaves and background albedo







- Regulates the ***absorption*** processes associated with vegetation photosynthesis

- No absorption process by vegetation associated with this wavelength-independent contribution

- Controlled by multiple scattering events between the background and the canopy

Ref: Pinty et al. (2004) Journal Geophysical Research, doi:10,1029/2004JD005214

Requirements from 2-stream model

- 3 (effective) state variables:

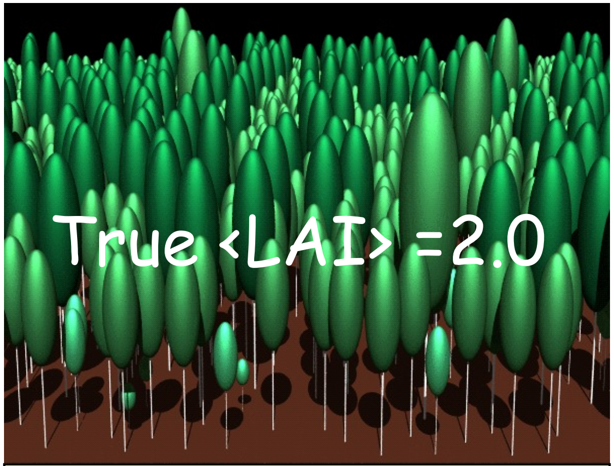
1. *Optical depth: LAI* **amount of leaf material**
2. *single scattering albedo :*
   Leaf reflectance+ Leaf transmittance **leaf color**
3. *asymmetry of the phase function*
   Leaf reflectance/transmittance

- 2 boundary conditions:

1. *Top: Direct and Diffuse atmospheric fluxes (known)*
2. *Bottom : Flux from* background Albedo *(unknown)* *soil color*

Pinty etal., (2006): Journal of Geophysical Research, doi:10.1029/2005JD00

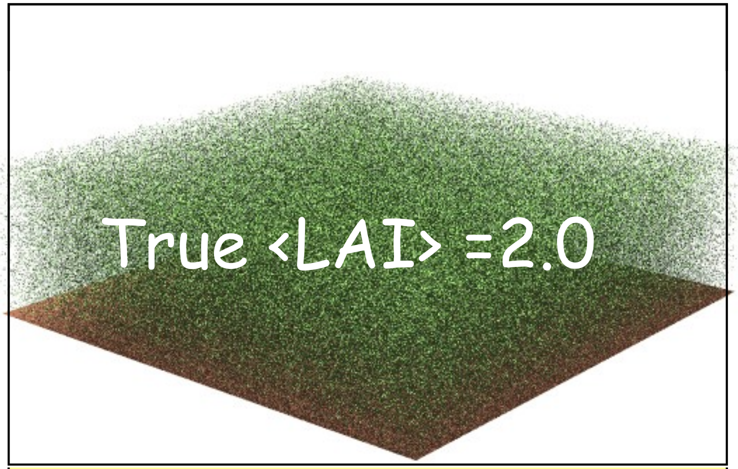
The concept of effective LAI



3-D heterogeneous system

Direct transmission at 30 degrees Sun zenith angle,

$$T^{direct}_{3-D}(<LAI>) = 0.596$$



1-D system representation

Direct transmission at 30 degrees Sun zenith angle,

$$T^{direct}_{1-D}(<LAI>) = \exp\left(-\frac{<LAI>}{2\mu_0}\right) = 0.312$$

Effects induced by internal variability of LAI

INPUTS : observations/model

- Remote Sensing Flux products, e.g. Albedo Vis/NIR, noted $\mathbf{d}$

- Updated/benchmarked 2-stream model from Pinty et al., noted $M(\mathbf{X})$

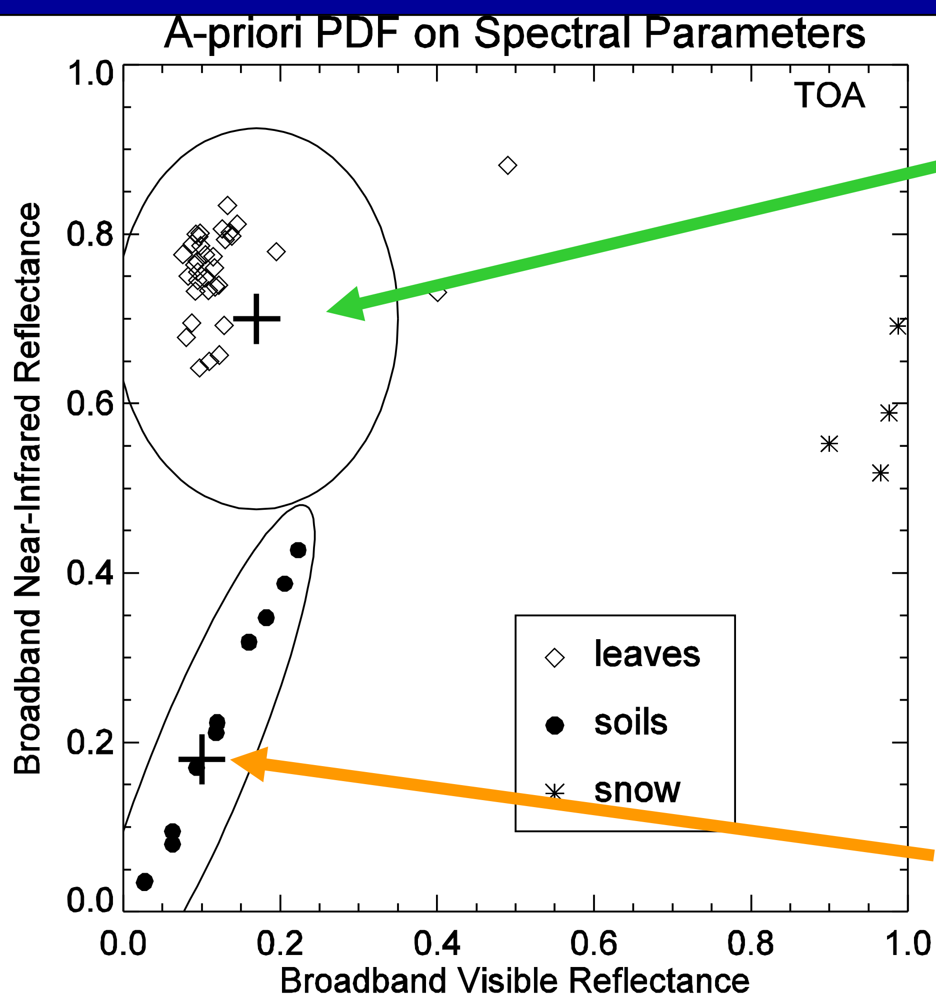
Pinty etal., (2006): Journal of Geophysical Research, doi:10.1029/2005JD005

INPUTS : observations/model

- Remote Sensing Flux products, e.g. Albedo Vis/NIR, noted $\mathbf{d}$
- uncertainty on the RS products is specified in the measurement set covariance matrix $\mathbf{C}_d$
- A priori knowledge/guess on model parameters noted $\mathbf{X}_{prior}$
- uncertainty associated the model parameter is specified via a covariance matrix $\mathbf{C}_{X_{prior}}$

Pinty etal., (2006): Journal of Geophysical Research, doi:10.1029/2005JD005

prior knowledge on model parameters

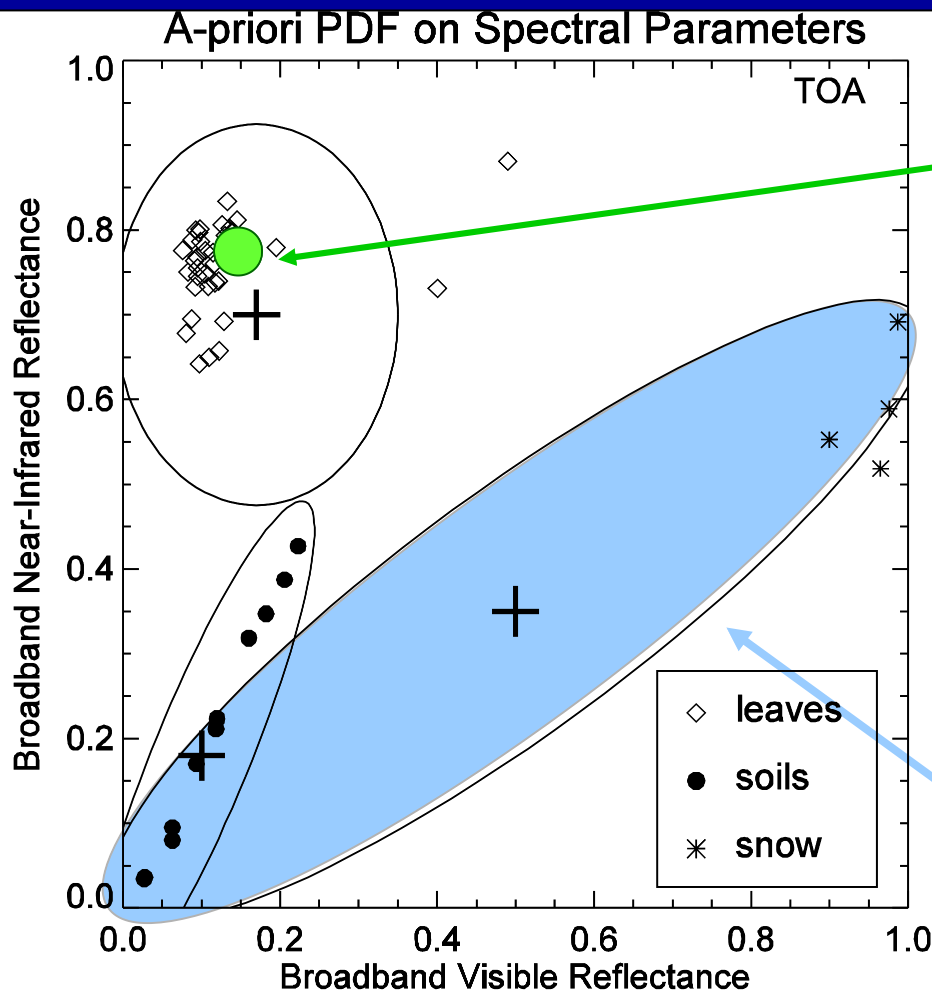


$$LAI_{prior} = 1.5$$

$$\sigma_{prior}(LAI) = 5.0$$

Pinty etal., (2007): Journal of Geophysical Research, doi:10.1029/2006JD008

prior knowledge on model parameters



a priori 'green' leaves

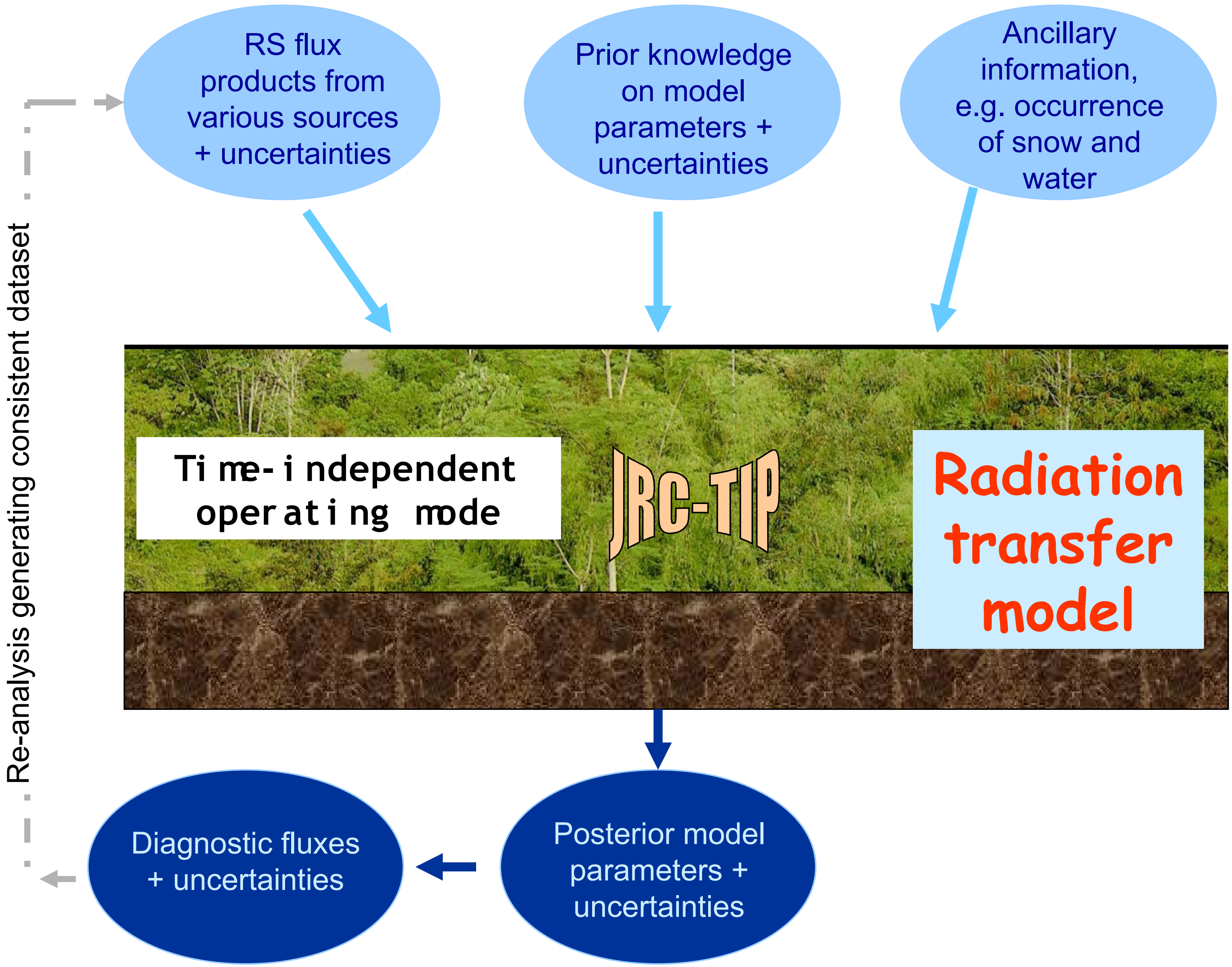
in case snow occurs

$$LAI_{prior} = 1.5$$

$$\sigma_{prior}(LAI) = 5.0$$

Pinty etal., (2007): Journal of Geophysical Research, doi:10.1029/2006JD008

JRC-Two-stream Inversion Package: JRC-TIP



The core of the JRC-TIP

$$J(\mathbf{X}) = \frac{1}{2}\left[\left(M(\mathbf{X}) - \mathbf{d}\right)^T \mathbf{C}_d^{-1}\left(M(\mathbf{X}) - \mathbf{d}\right) + \left(\mathbf{X} - \mathbf{X}_{prior}\right)^T \mathbf{C}_{X_{prior}}^{-1}\left(\mathbf{X} - \mathbf{X}_{prior}\right)\right]$$

Model parameters

2-stream model

measurements

Parameter knowledge

Uncertainty measurements

Uncertainty parameters

- Computer optimized Adjoint and Hessian model of cost function from automatic differentiation technique (assume Gaussian theory).
- PDFs of all 2-stream model parameters
- Assessment of all fluxes predicted by the 2-stream model and their associated uncertainty

Pinty etal., (2007): Journal of Geophysical Research, doi:10.1029/2006JD00

OUTPUTS: posterior knowledge

- PDFs of all 2-stream model parameters:

$$PDF(\mathbf{X}) \approx \exp\left(-\frac{1}{2}(\mathbf{X}-\mathbf{X}_{post})^T \mathbf{C}_{X_{post}}^{-1} (\mathbf{X}-\mathbf{X}_{post}) \right)$$

a posteriori uncertainty covariance matrix

- Assessment of all fluxes predicted by the 2-stream model and their associated uncertainty:

$$\mathbf{C}_{post}^{Flux} = \mathbf{G}\mathbf{C}_{X_{post}}\mathbf{G}^T$$

Pinty etal., (2007): Journal of Geophysical Research, doi:10.1029/2006JD00

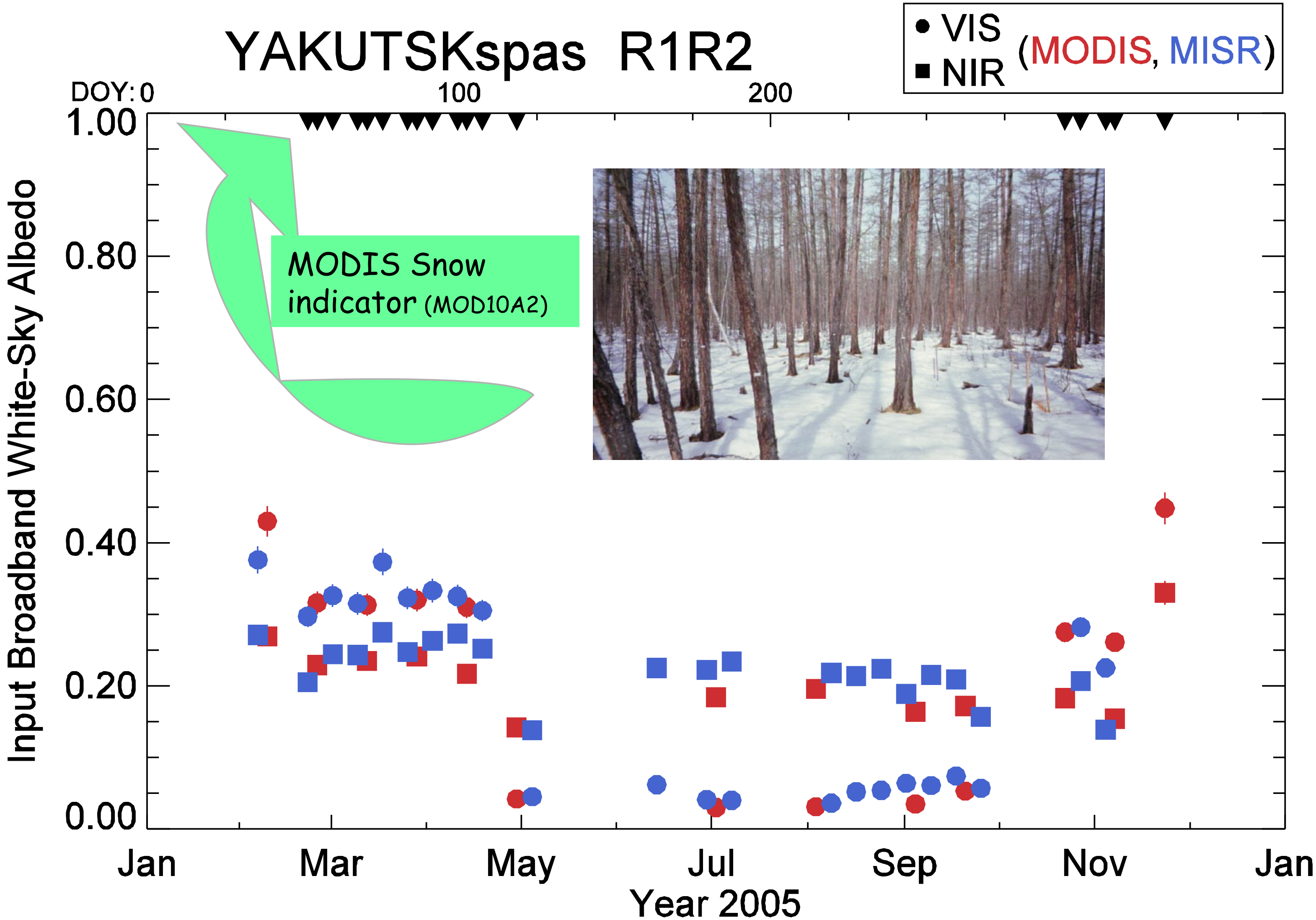
Operational Processing of MODIS – MISR albedo products

JRC-TIP applied to global scale, 1 Km resolution yearly time-series (2005) of MODIS and MISR albedos (BHRs).

	Total Number of Inversions	Valid Results (%)	Solution not Found (%)	High Residual misfit (%)
MODIS	1.88×10^8	98.1	1.84	0.11
MISR	2.72×10^8	93.8	4.24	1.99

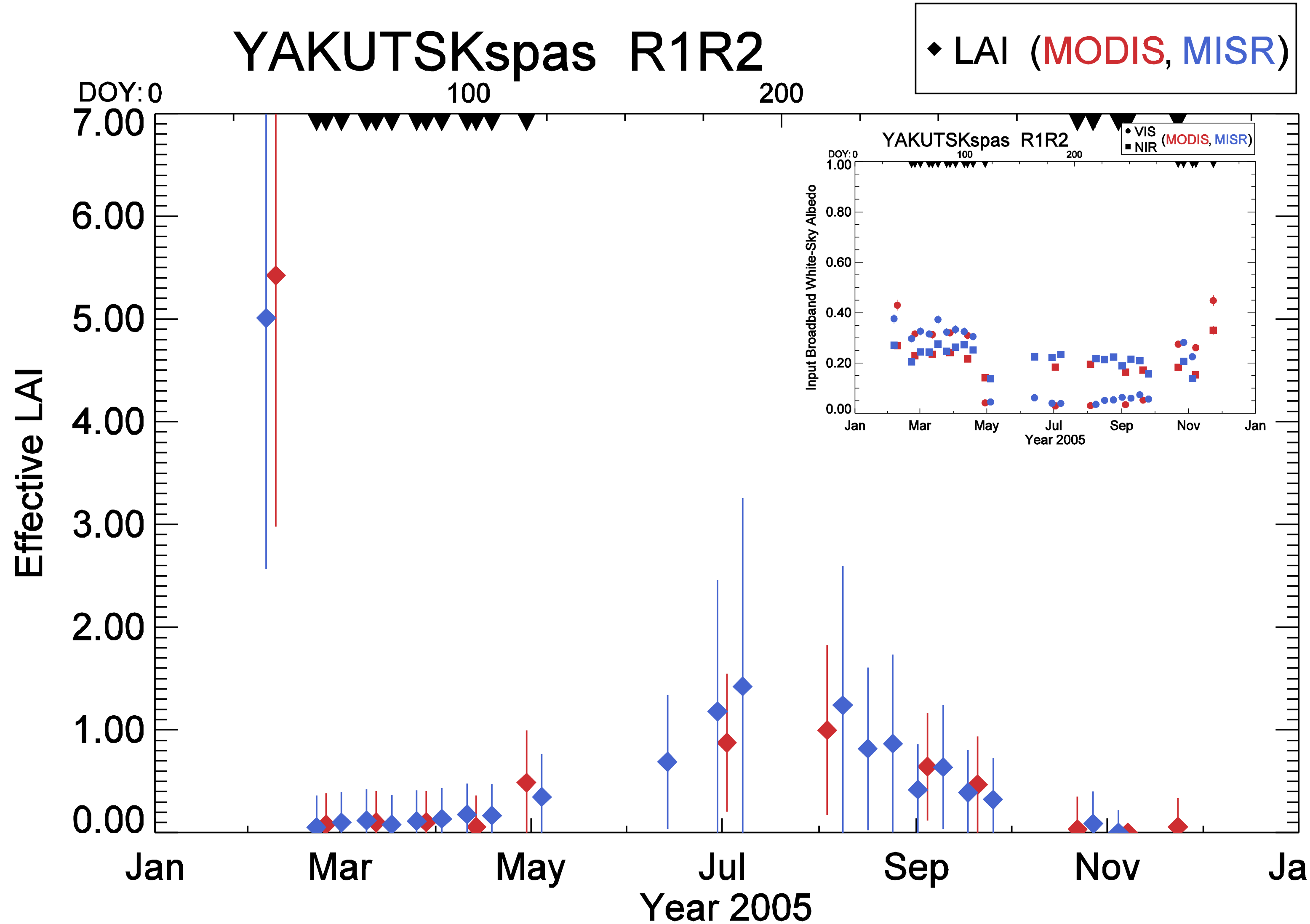
Application over Yakustk Forest: a deciduous needle-leaf larch forest

Application over Yakutsk: Measurements



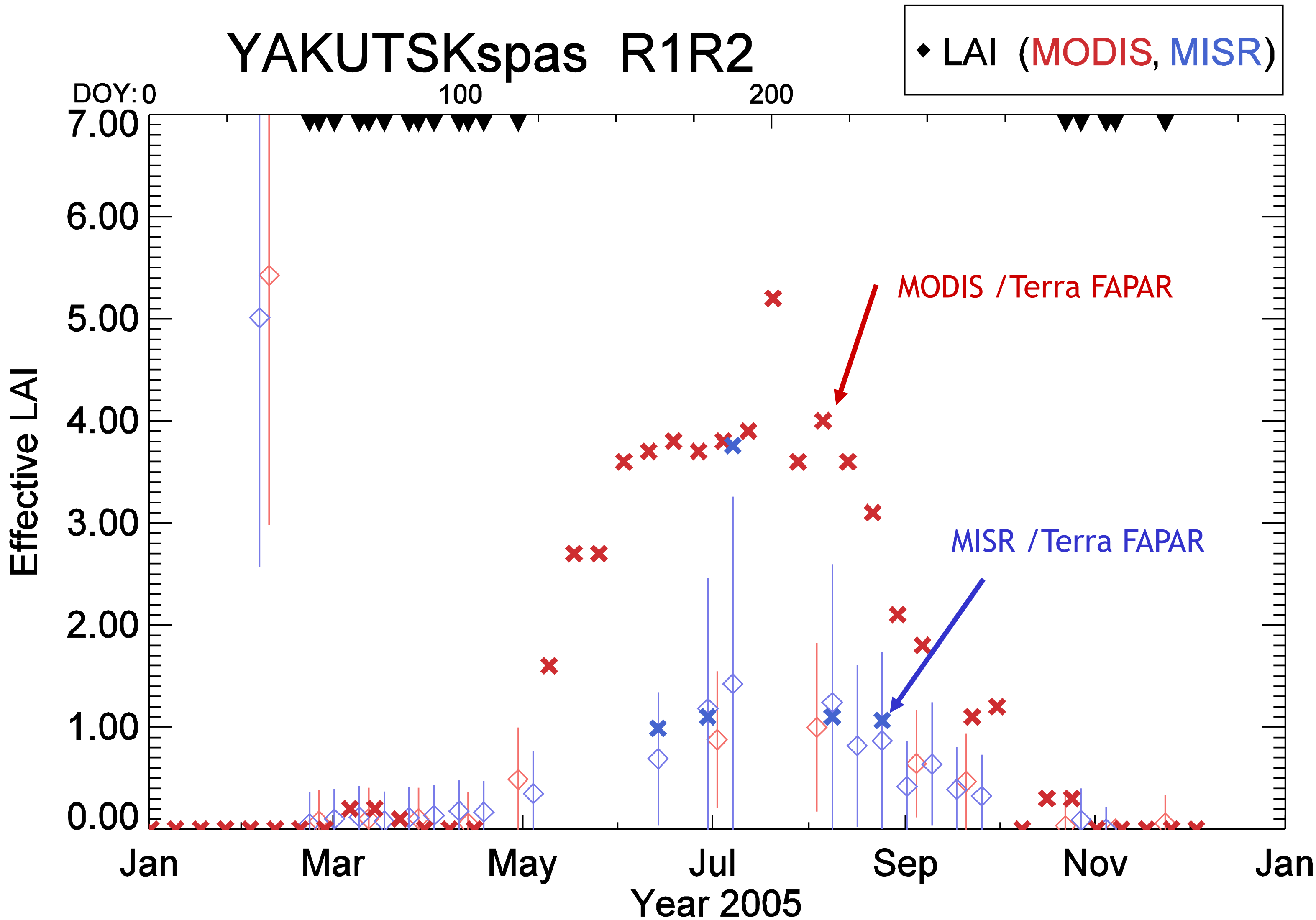
Specified uncertainty on BHRs is 5% relative

Application over Yakutsk: model parameters



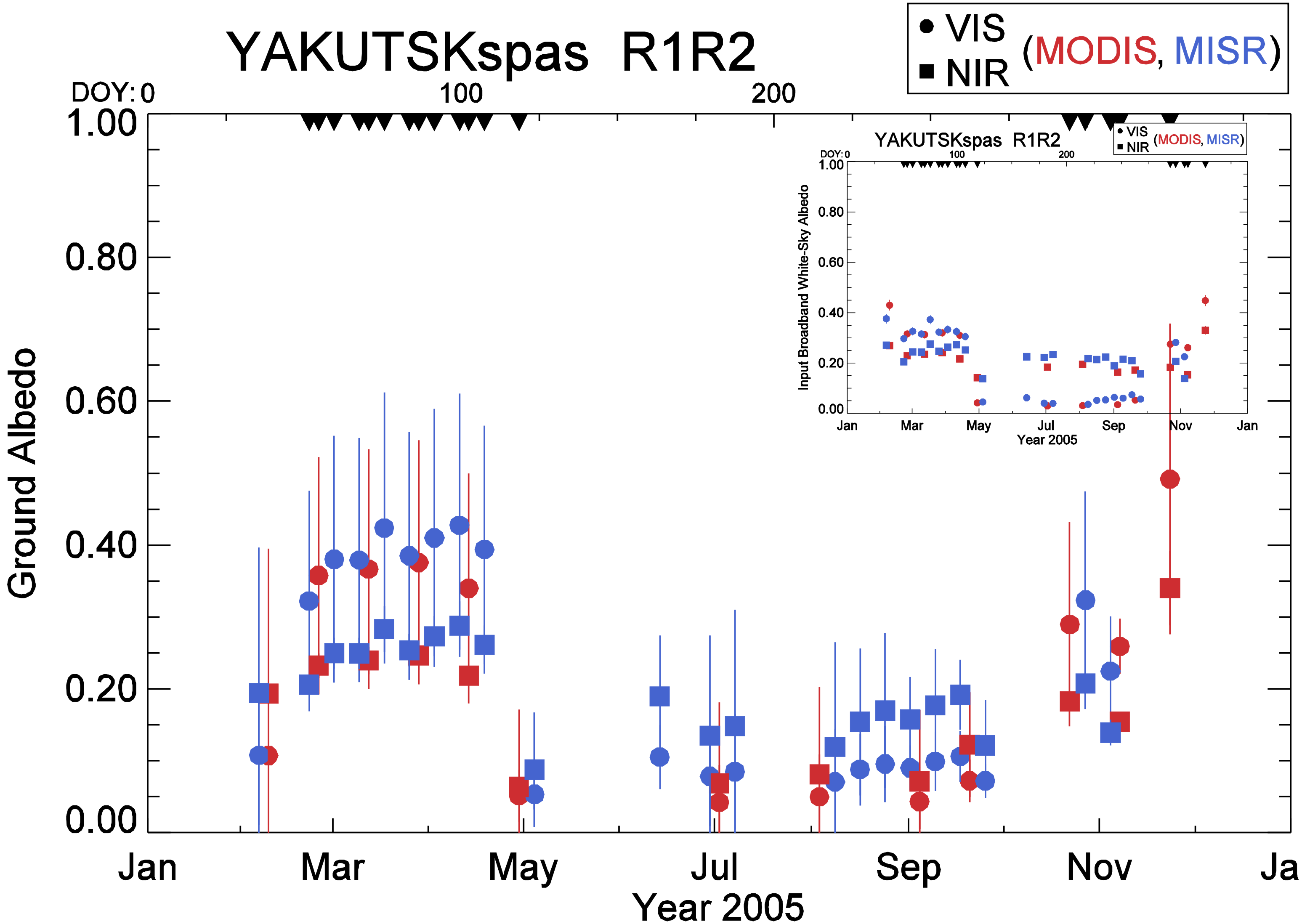
Pinty etal., (2008): Journal of Geophysical Research, doi:10.129/2007/JD00

Application over Yakutsk: model parameters



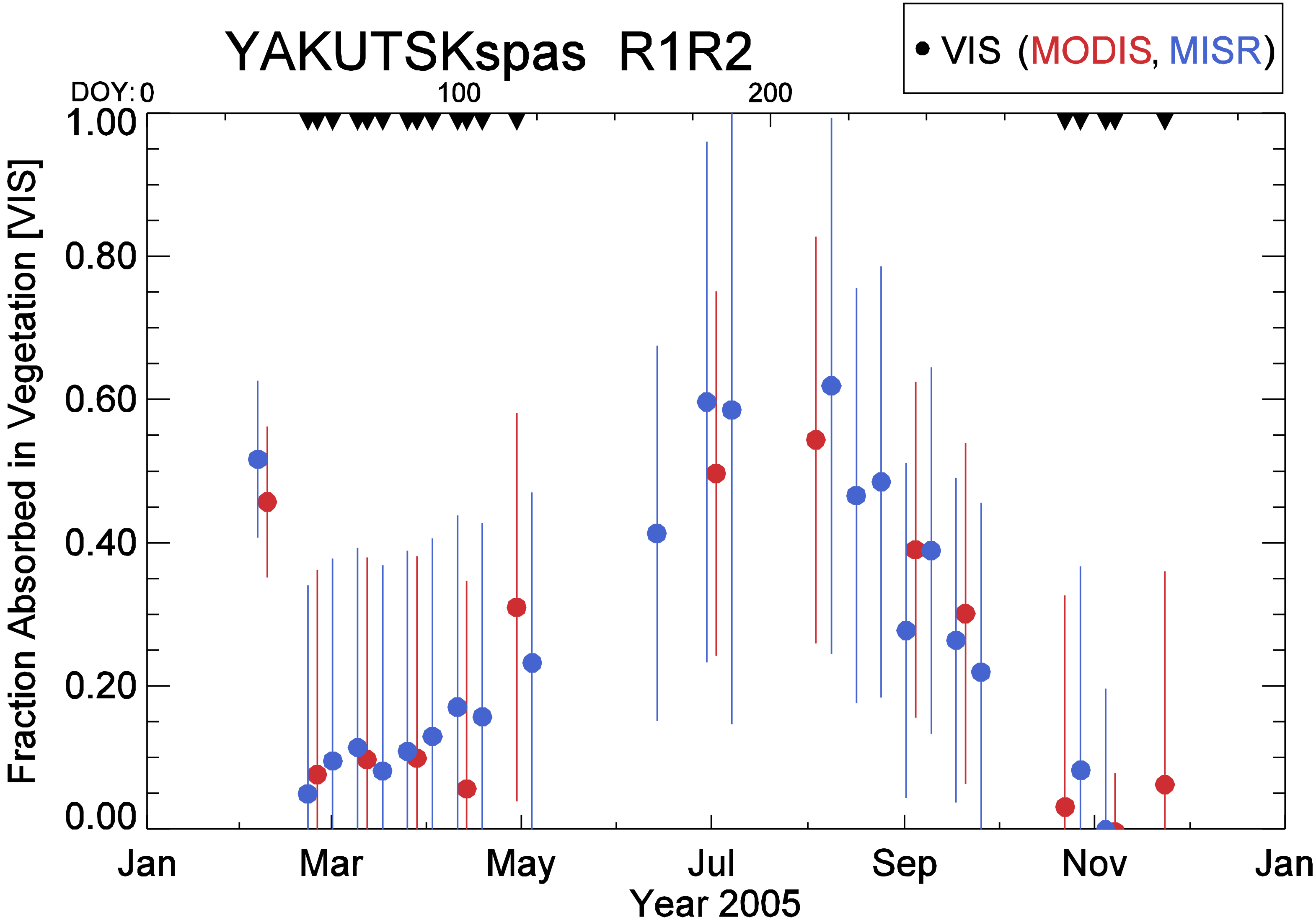
Pinty et al., (2008): Journal of Geophysical Research, doi:10.129/2007/JD009

Application over Yakutsk: model parameters



Pinty etal., (2008): Journal of Geophysical Research, doi:10.129/2007/JD00

Application over Yakutsk: radiant fluxes



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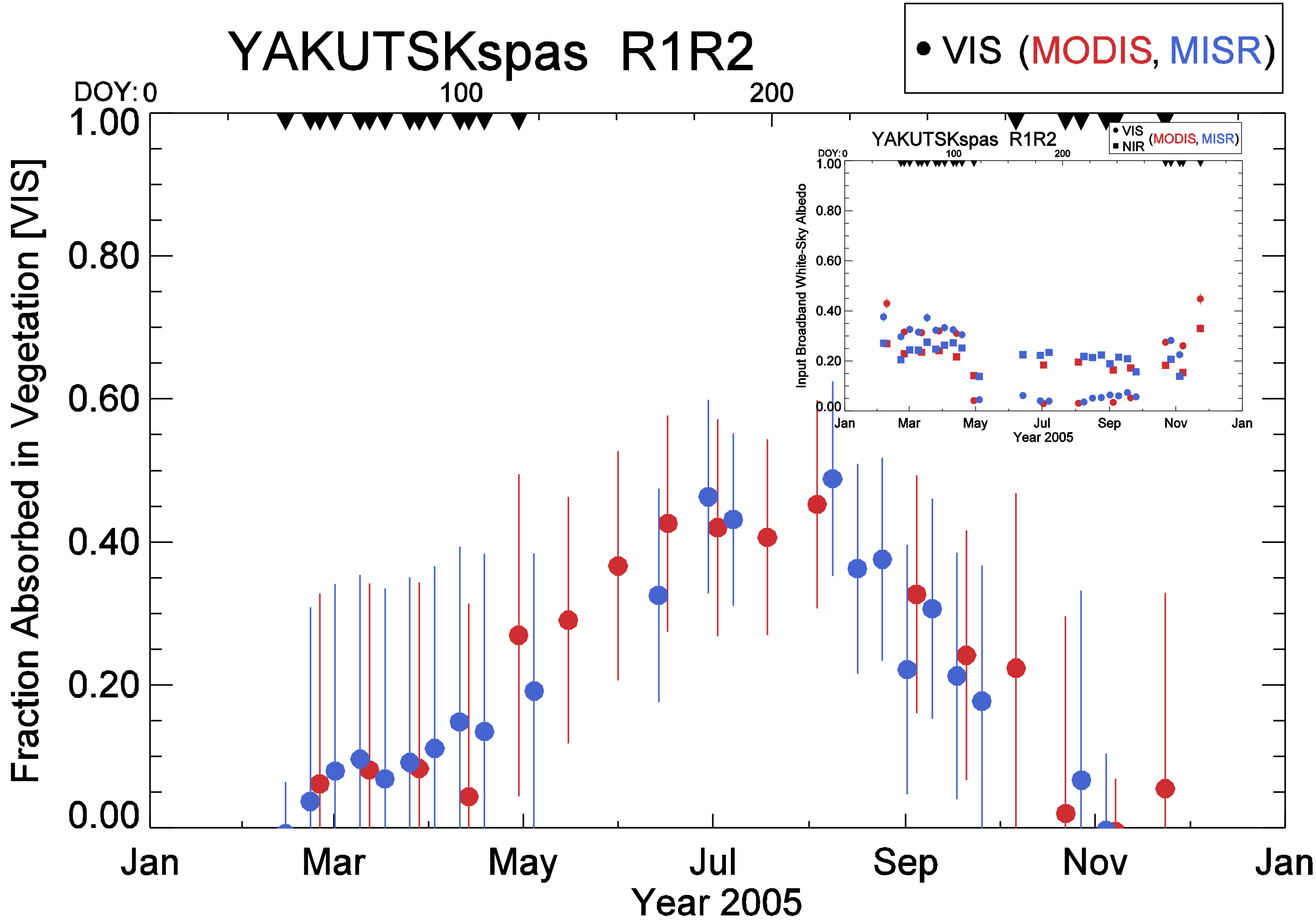

a priori 'green' leaves

Pinty etal., (2008): Journal of Geophysical Research, doi:10.129/2007/JD00

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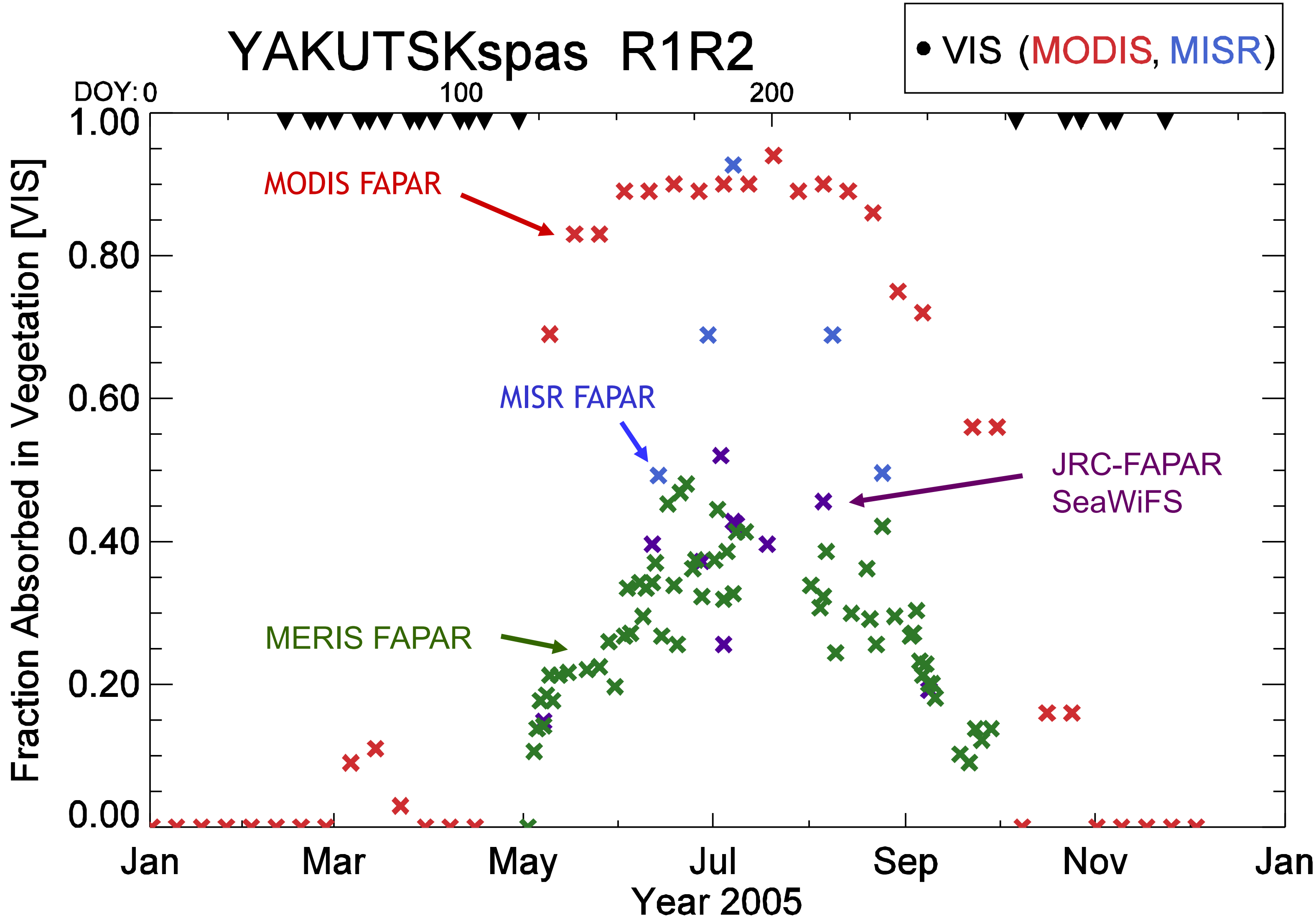

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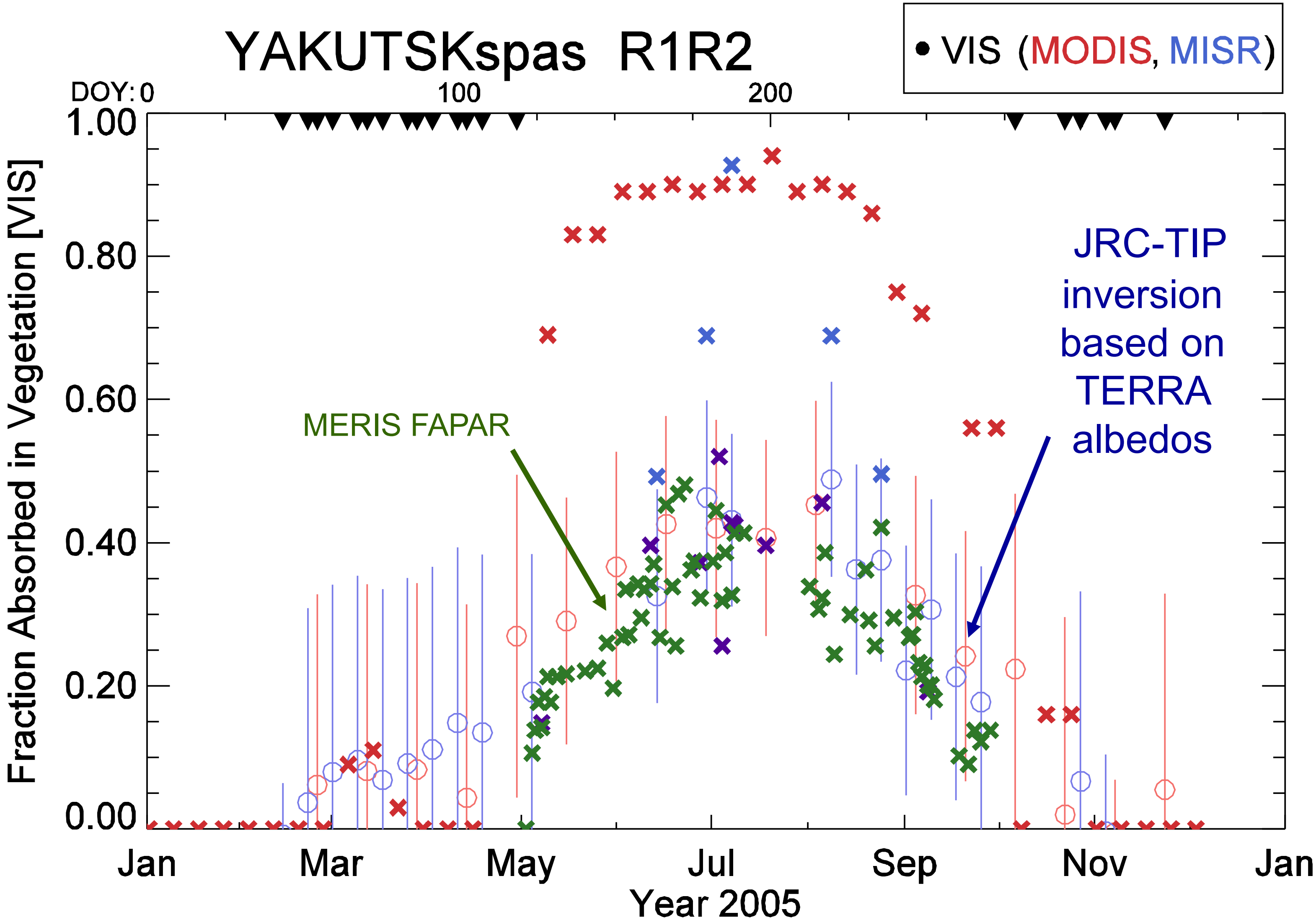

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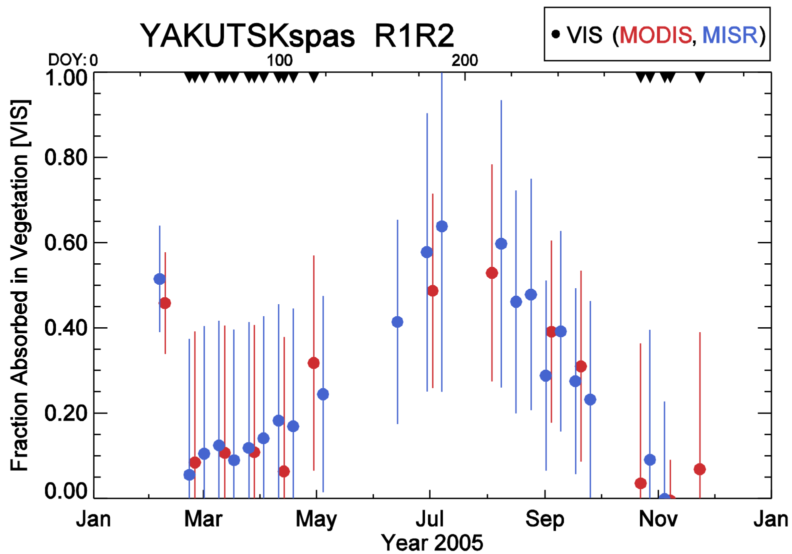
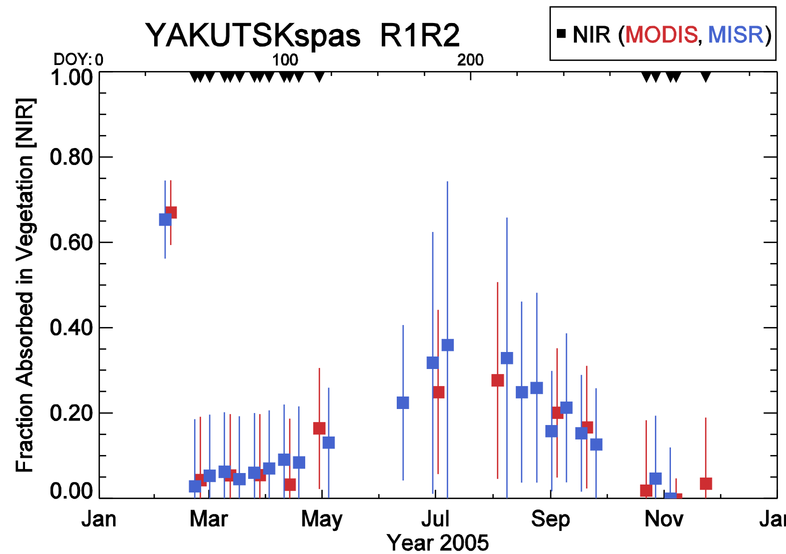
Partitioning of the absorbed fluxes

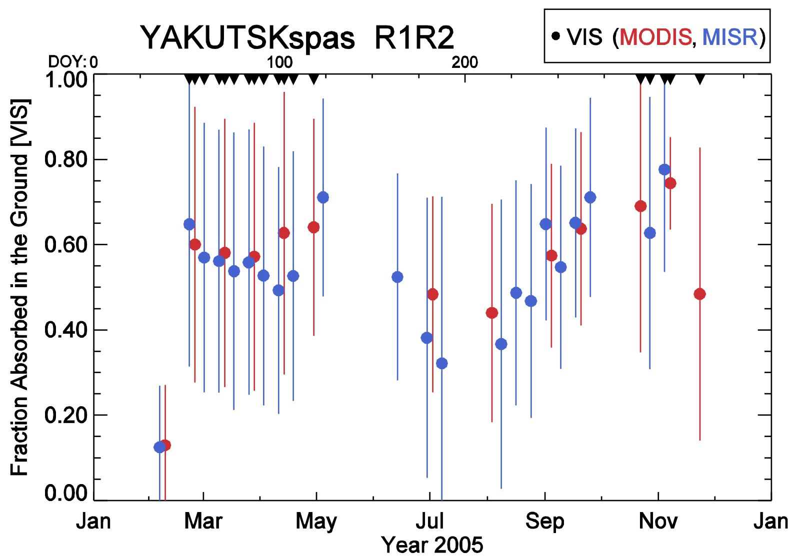
VISIBLE | **NEAR-INFRARED**

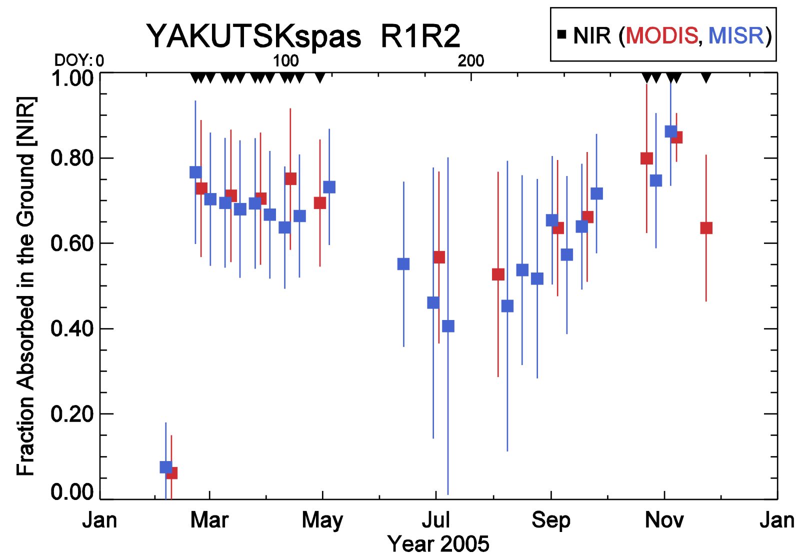
VEGETATION





SOIL





Pinty etal., (2008): Journal of Geophysical Research, doi:10.129/2007/JD00

Add some examples over Northern region

Rukolahti period 161_16

map with R=0.4 G=3.0 B=0.4

case of agriculture:

61 56 06 and 28 55 29

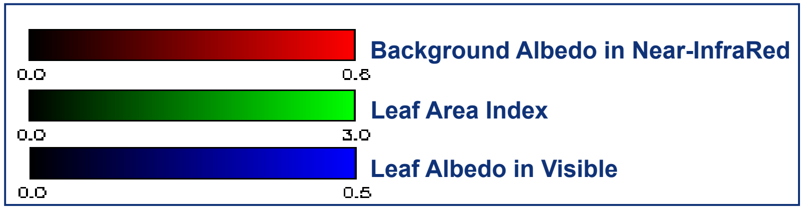
Case of forest

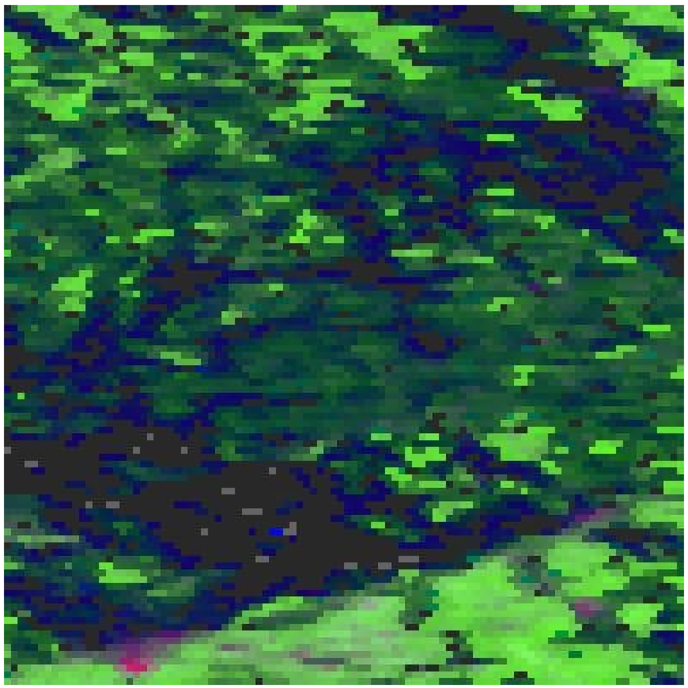
Then map period 241_16

With R=0.4 G=0.8 and B= 0.3

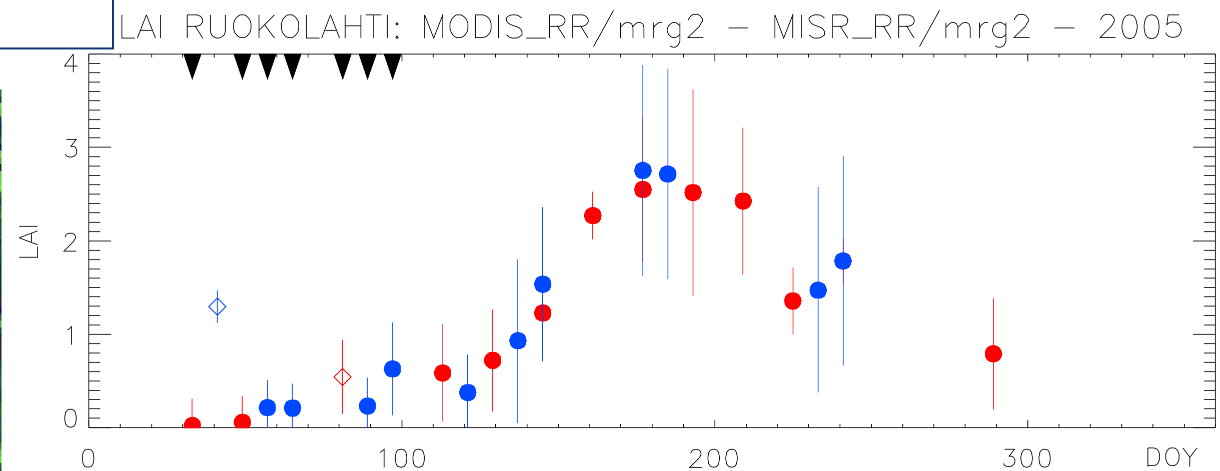
41 36 17 and 7 39 53

Application over Finland: Agriculture

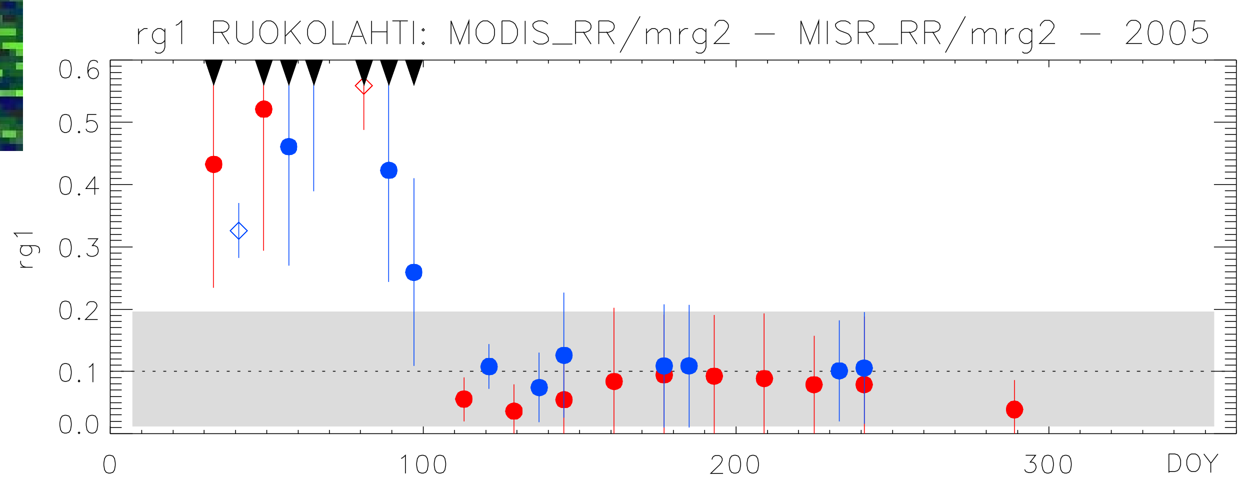




Leaf Area Index



Background albedo (visible)



Add some examples

Portugal period 145_16

map with R=0.4 G=3.0 B=0.4

case of agriculture:

41 53 42 and 7 49 29

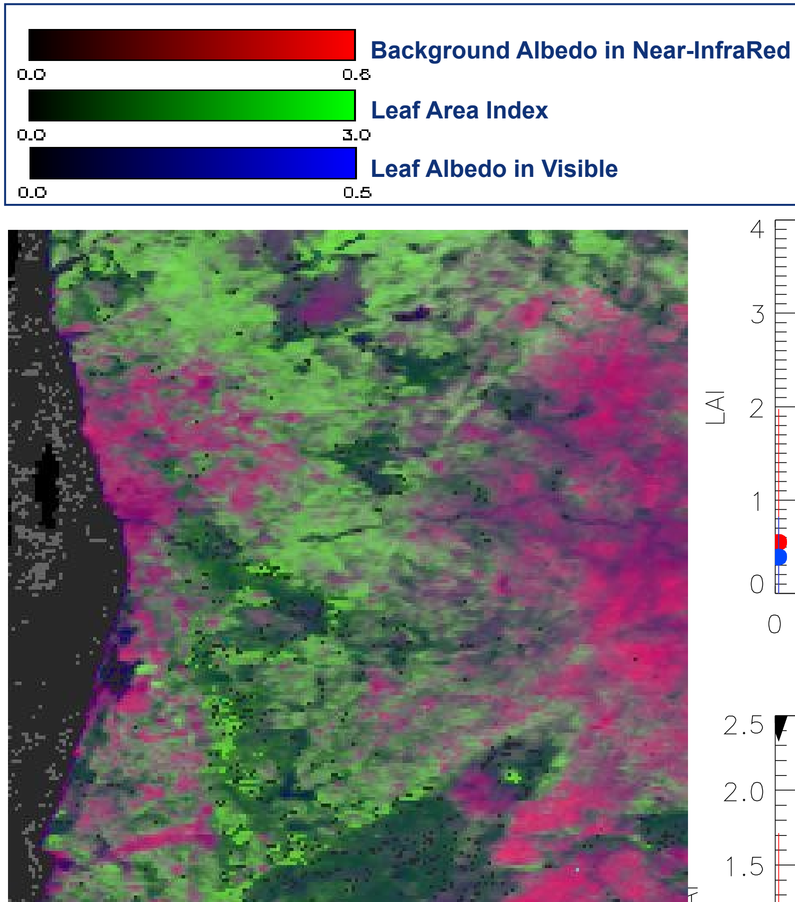
Case of fire

Then map period 241_16

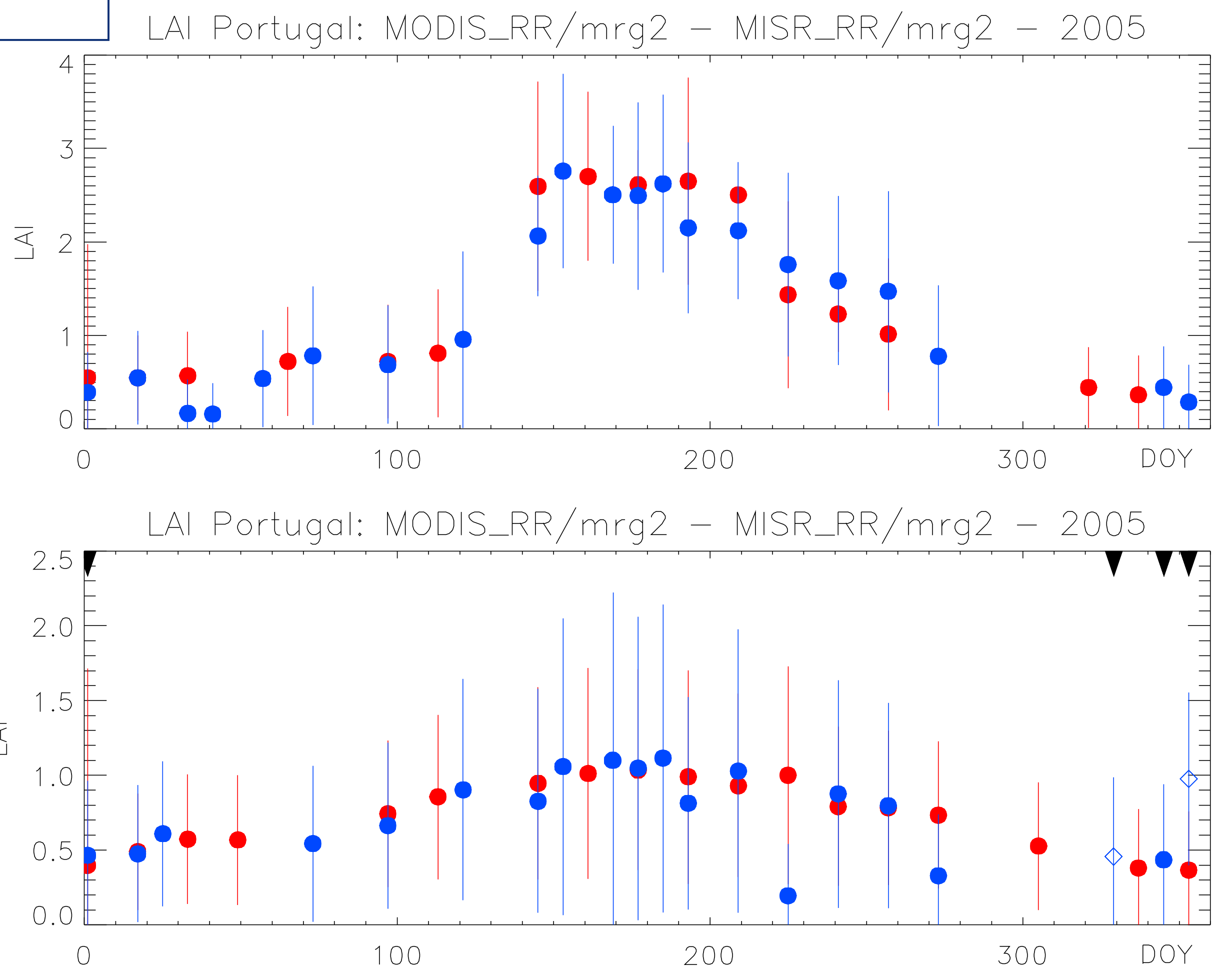
With R=0.4 G=0.8 and B= 0.3

41 36 17 and 7 39 53

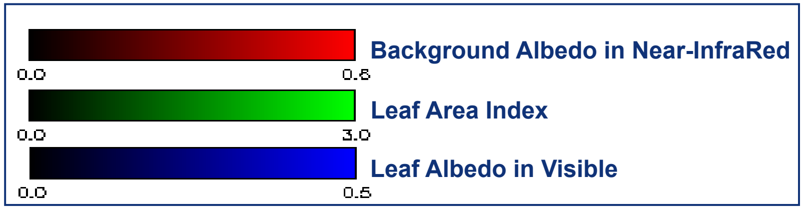
Application over Portugal: Agriculture

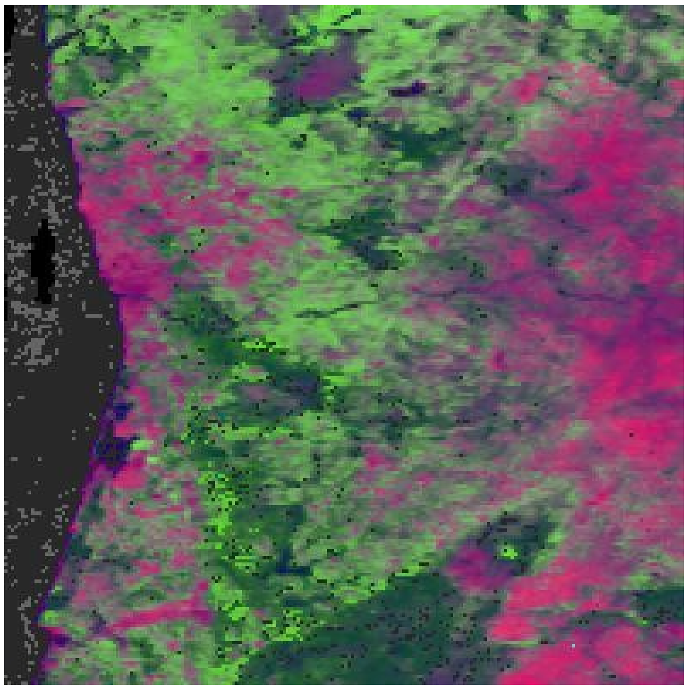


Leaf Area Index

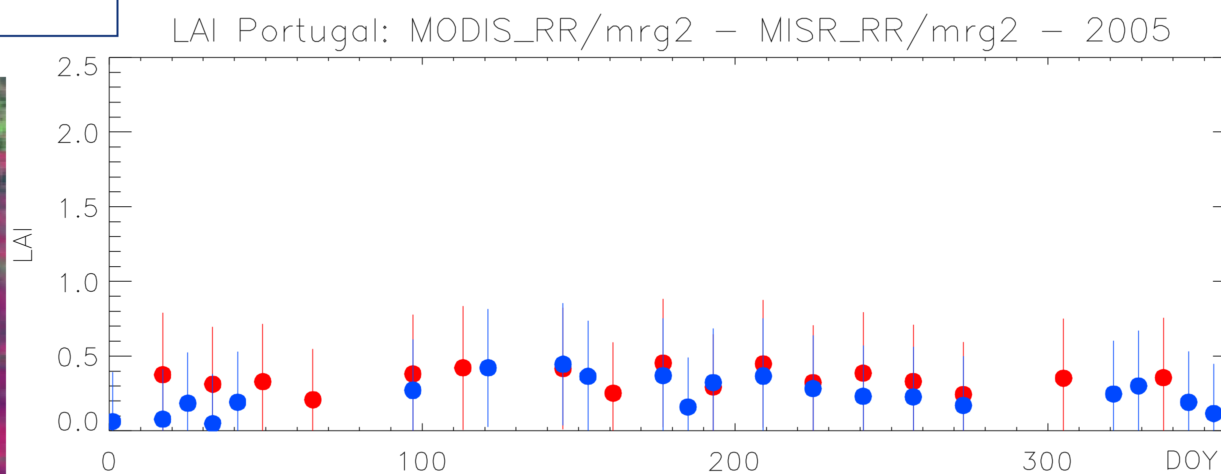


Application over Portugal: sparse vegetation

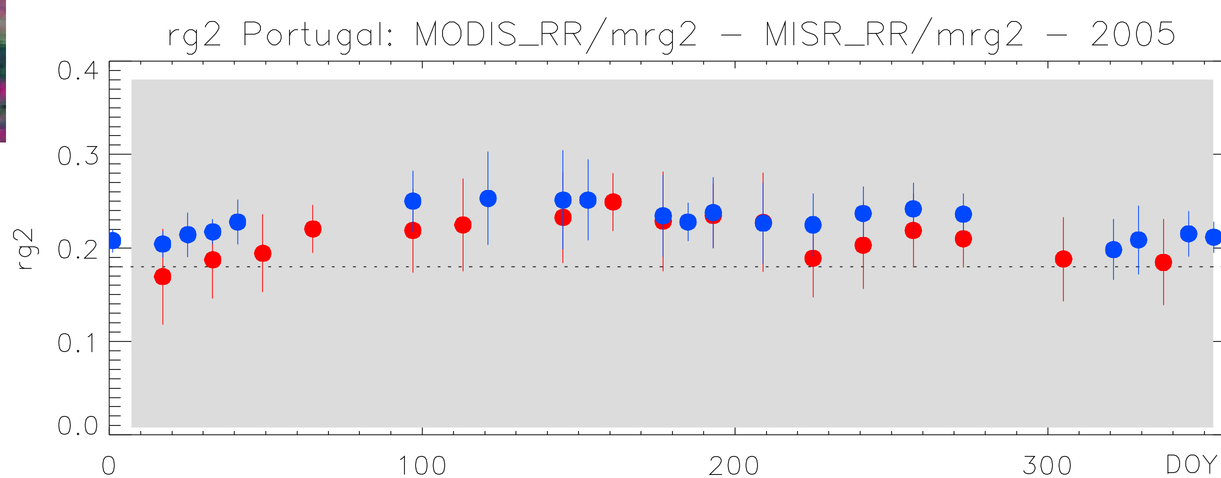




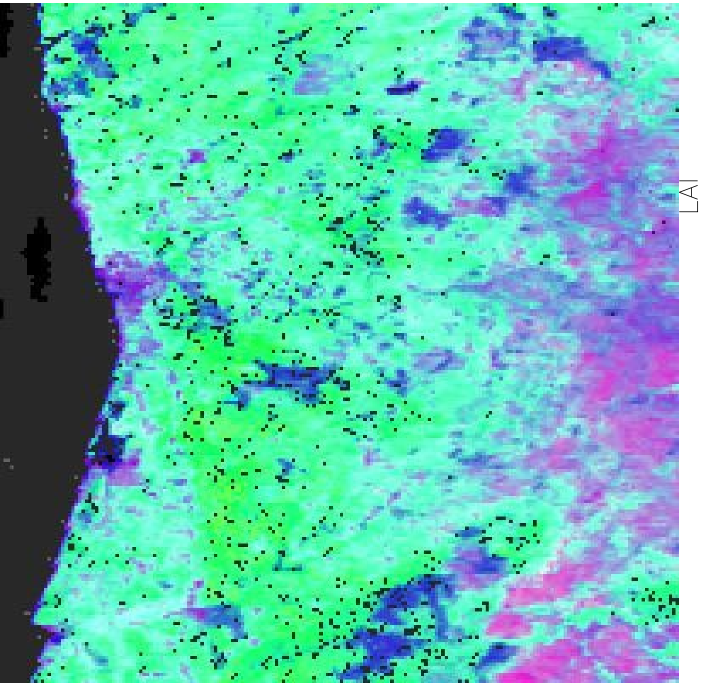
Leaf Area Index



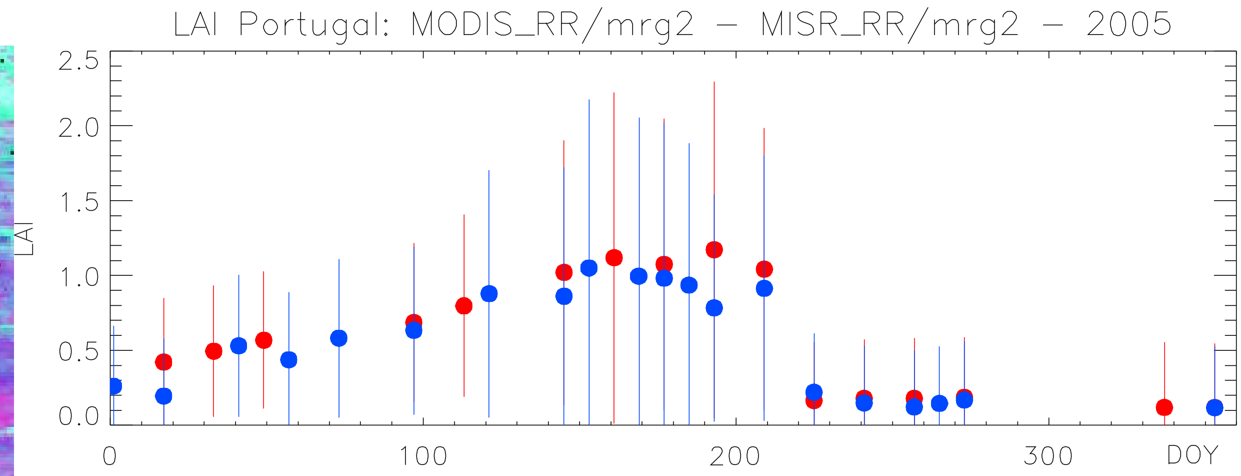
Background albedo (NIR)



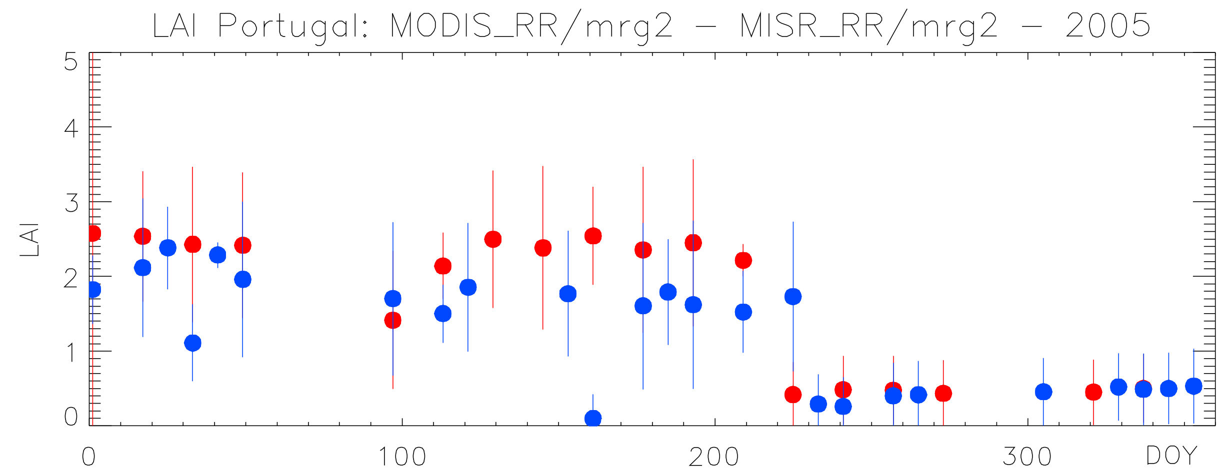
Application over Portugal: Burnt vegetation



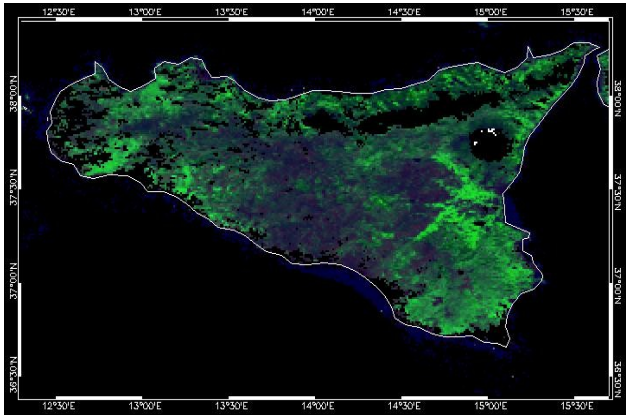
Leaf Area Index

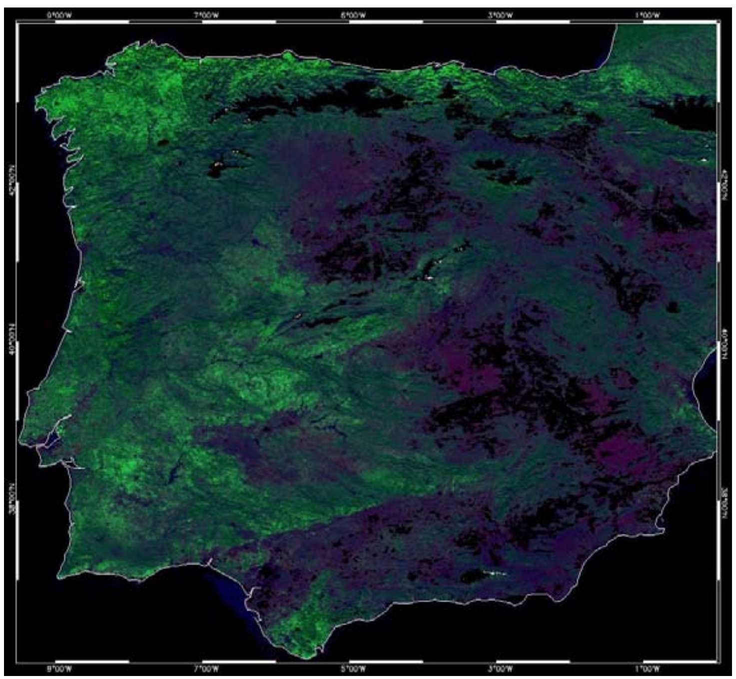


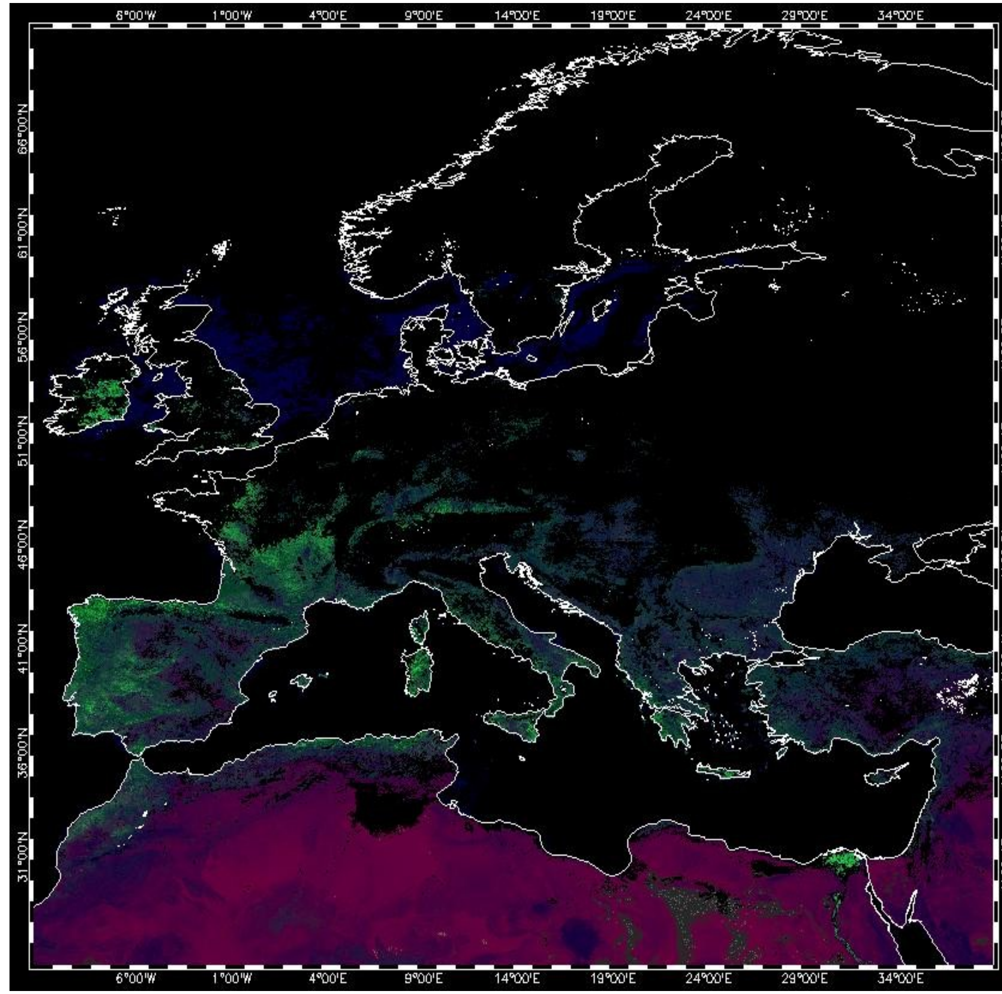
Leaf Area Index



January 2005







0.0 – 1.5 Soil Albedo in NIR

0.0 – 3.0 Leaf Area Index

0.0 – 0.7 Leaf Albedo in Visible

No solution found

High residual cost-function

Snow Prior used

Expected benefits

1. Derive consistent set of radiation fluxes in vegetation and soil layers (R, A and T + uncertainties) optimized against albedo products available from different sensors… and by-products.

2. Establish a quite comprehensive baseline against which historical records can be exploited.

3. Provide strong predictive capabilities for land surface monitoring needed for many applications.

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1. Derive consistent set of radiation fluxes in vegetation and soil layers (R, A and T + uncertainties) optimized against albedo products available from different sensors…and by-products.

2. Establish a quite comprehensive baseline against which historical records can be exploited.

1. Derive land surface variables, e.g., LAI, leaf and soil colors to produce Land Cover maps under a controlled environment! ..new paradigm?

1. Provide strong predictive capabilities for land surface monitoring needed for many applications.