Joint Research Centre

Partitioning the solar fluxes in vegetation Canopies from operational MODIS and MISR surface albedo products

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with contributions from
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FastOpt, Hamburg, Germany

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Institute for Environment and Sustainability

Complex land-surface RT effects on short term climate: the snow case with ECMWF/NCEP

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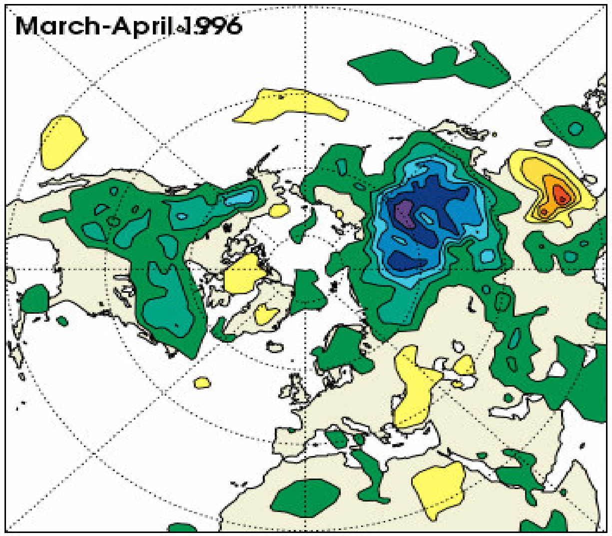
FEATURES

glossary on off

1 ◀ ▶ 3

Everyone Complains About the Weather…

Betts and his BOREAS colleagues observed that, in the spring, daily weather forecasts significantly underestimated air temperatures over the boreal forest, sometimes by as much as 10—15°C (18—27°F) (Viterbo and Betts, 1999). Additionally, the BOREAS team found that predictions of cloud cover over the boreal region were often far off the mark. Everyone complains about the weather, but how could the forecasts be so wrong so often?



This map shows the average errors in the European Centre for Medium-Range Weather Forecasts at 850mb (roughly equivalent to an altitude of 1500m) for March and April of 1996. The predictions, made five days in advance, were compared to actual measurements. The 1996 model did not include the adjustments to forest albedo.

(Figure from Viterbo, P. and A.K. Betts, 1999: The impact on ECMWF forecasts of changes to the albedo of the boreal forests in the presence of snow. J. Geophys. Res. (In press, BOREAS special issue). Courtesy A.K. Betts)

Forecast Errors (°C)

-7 -5 -3 +1 +3 +5

The scientists noticed a pattern that confirmed their earlier suspicions: the temperature forecasts were farthest off in late spring when snow was on the ground and grew more accurate after the snow melted. From summer through fall, the weather models matched actual measurements more

Ref: Viterbo and Betts, 1999, JGR

"…weather forecasts significantly underestimated air temperatures over boreal, sometimes by as much as 10-15 C…"

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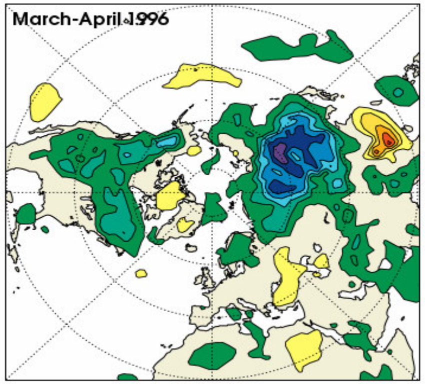

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"…—the BOREAS team found that the models were overestimating **albedo** (the amount of **light** reflected by the surface). …"

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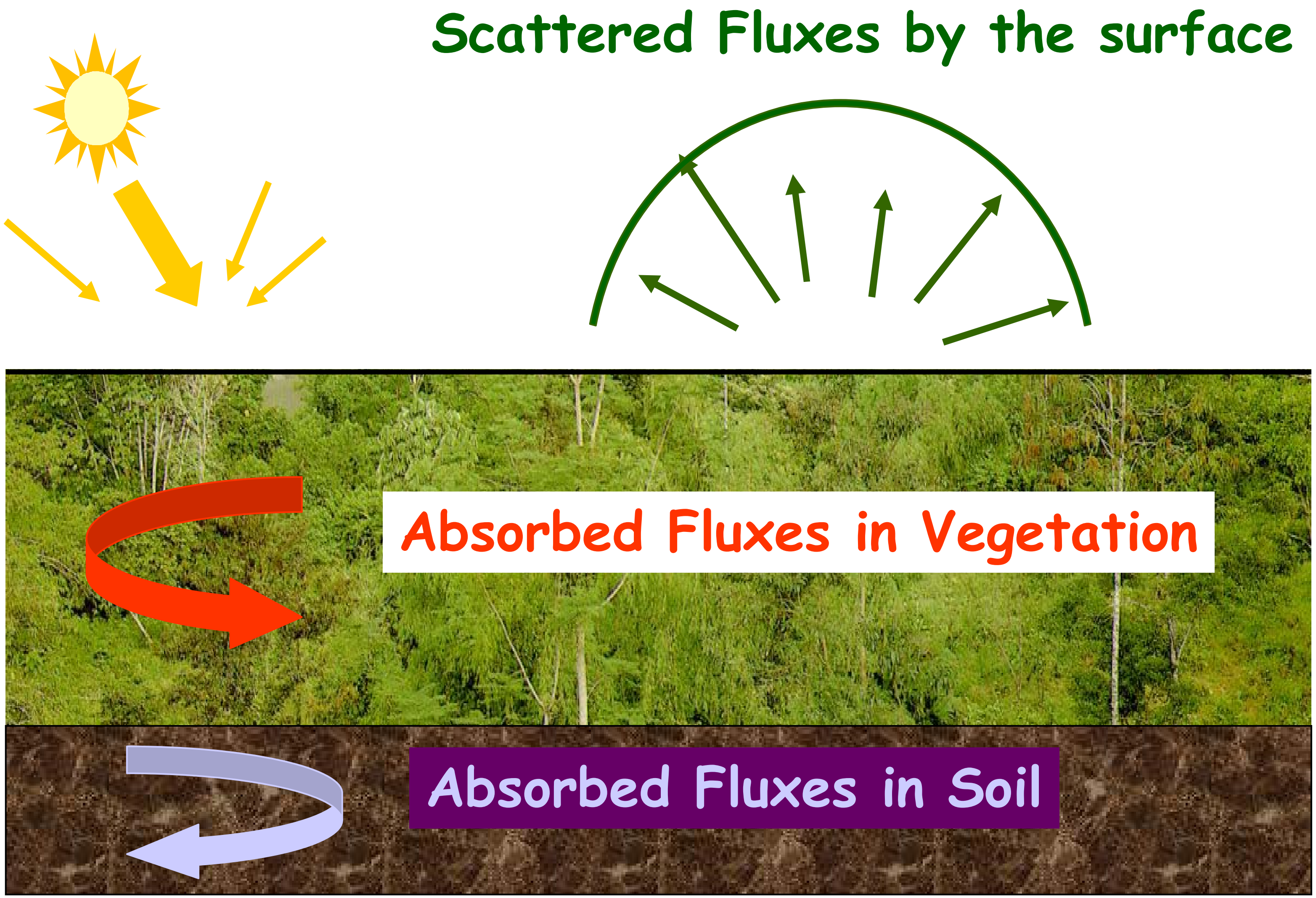
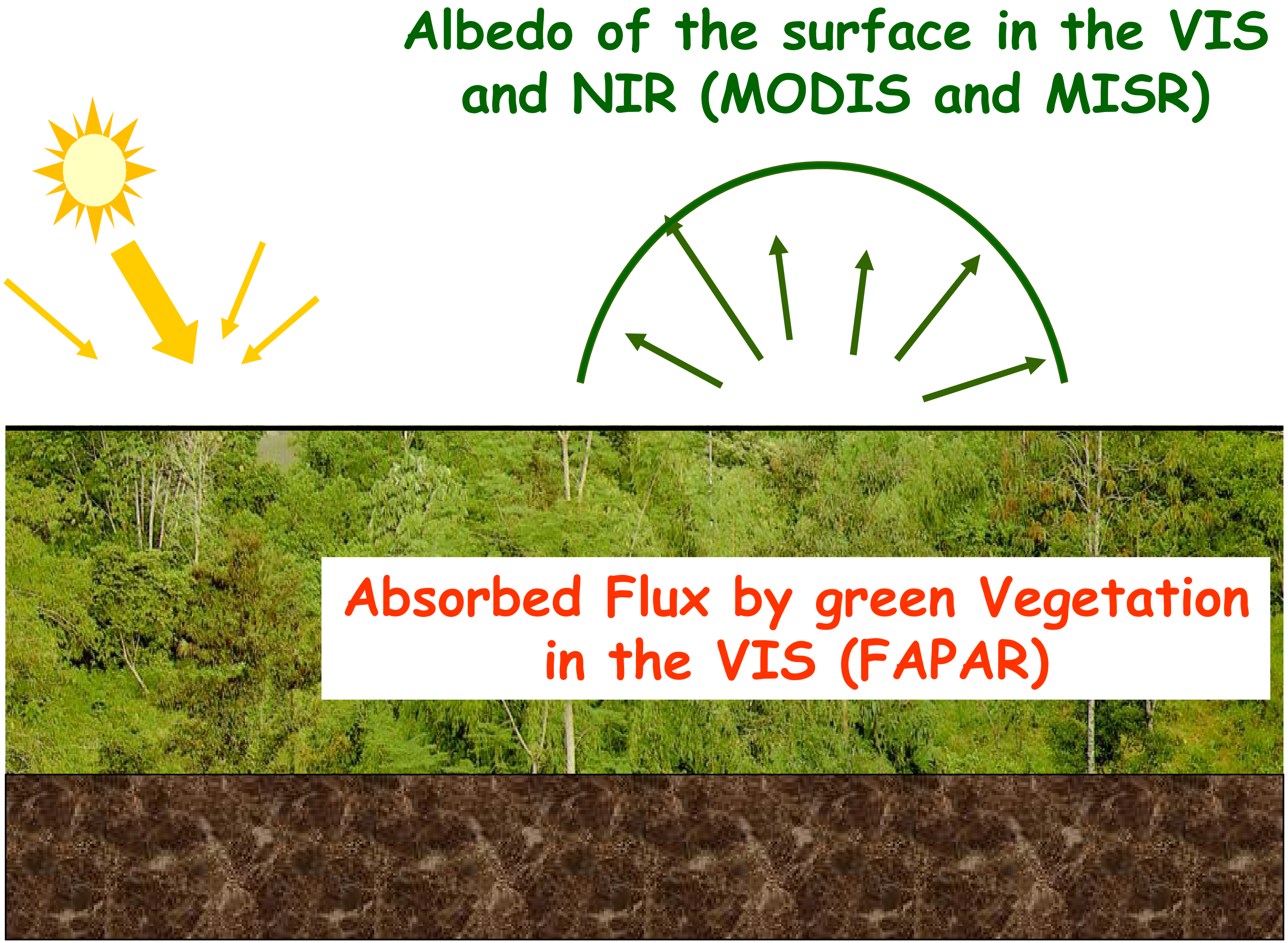
How does radiation redistribute energy between the atmosphere and the biosphere?



What do we measure at global scale that we should model as well?



How do we model the absorbed fluxes in vegetation and soil ?

Correct partitioning between the flux that is absorbed :

1- in the vegetation layer

VIS VIS+NIR

$$\boxed{A_{veg}} = 1 - \boxed{ALB_{sfc}} - A_{ground}$$

2- in the background

$$A_{ground} = T_{veg}(1 - \alpha_{ground})$$

Assessment of the fraction of solar radiant flux that is scattered (albedo) by, transmitted through and absorbed in the vegetation layer

Pinty etal., (2006): Journal of Geophysical Research, doi:10.1029/2005JD00595

What are the needs?

- Update/improve the current Land Surface schemes describing the radiation transfer processes in vegetation canopies

  see 2-stream model by Pinty et al. JGR (2006).

Requirements from a 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*

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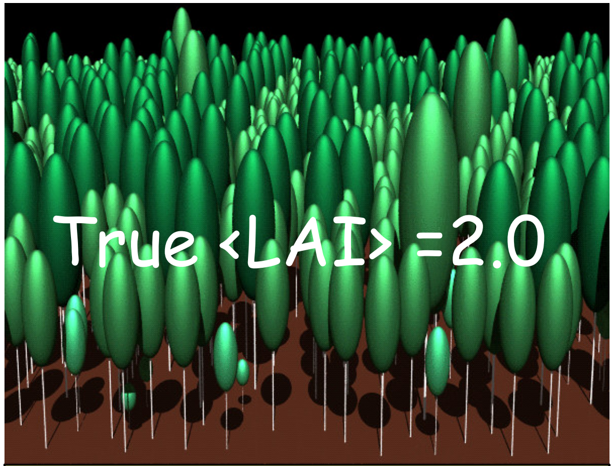
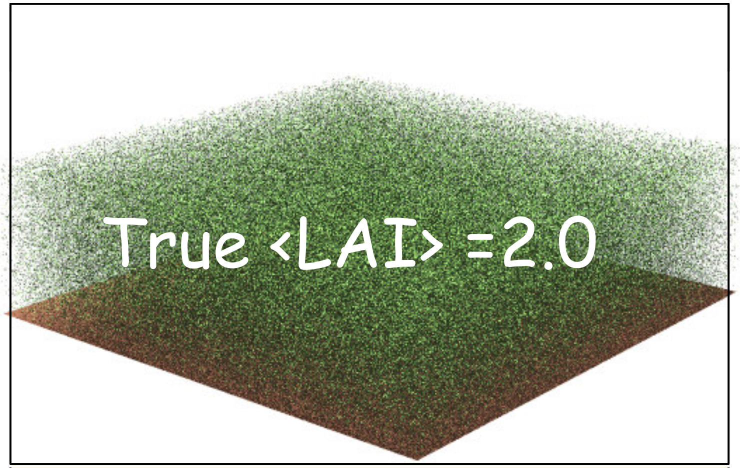
The concept of effective LAI



3-D heterogeneous system



1-D system representation

Direct transmission at 30 degrees Sun zenith angle,

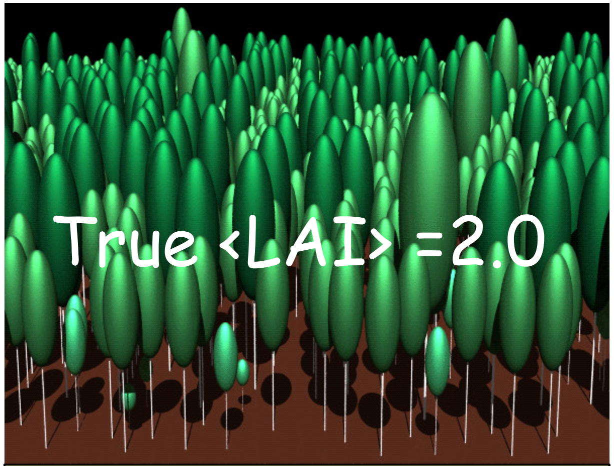
$$T_{3-D}^{direct}(<LAI>) = 0.596$$

Direct transmission at 30 degrees Sun zenith angle,

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

Effects induced by internal variability of LAI

The concept of effective LAI



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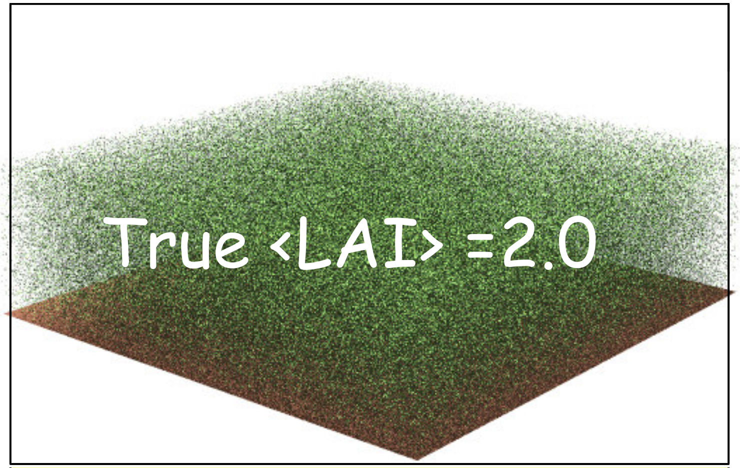

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$$T_{1-D}^{direct}(LAI^{eff}) = \exp\left(-\frac{LAI^{eff}}{2\mu_0}\right) = \exp\left(-\frac{<LAI>\xi(\mu_0)}{2\mu_0}\right) = T_{3-D}^{direct}(<LAI>)$$

Structure factor

What are the needs?

- Update/improve the current Land Surface schemes describing the radiation transfer processes in vegetation canopies

  see 2-stream model by Pinty et al. JGR (2006).

- Prepare for the ingestion/assimilation of RS flux products into Land Surface schemes

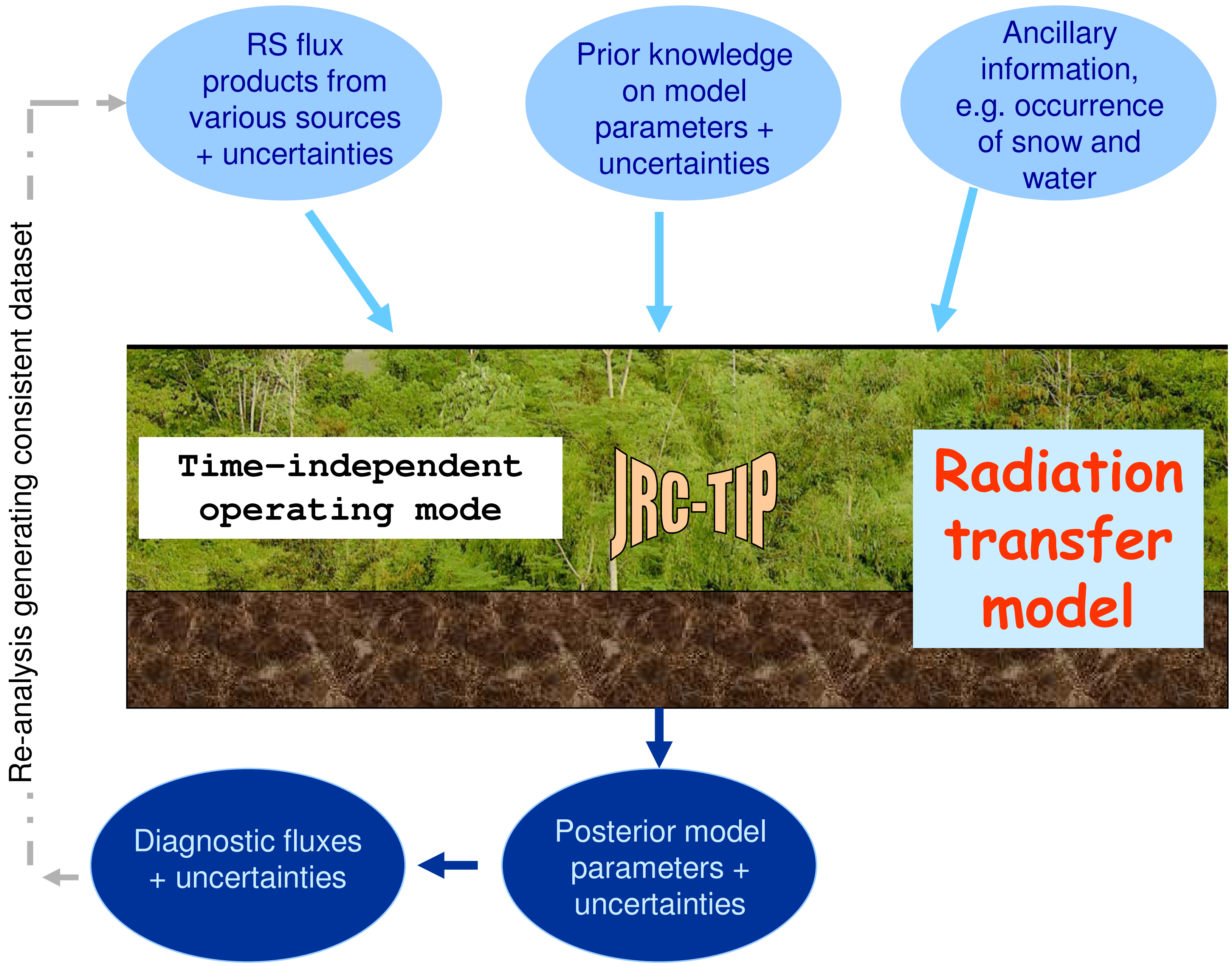
  Retrieve 2-stream model parameters from RS flux products

Retrievals of model Parameters for Land surface schemes

The inverse problem can 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

JRC-Two-stream Inversion Package: JRC-TIP



INPUTS : prior knowledge

- RS Flux products, e.g., Albedo Vis/NIR and/or FAPAR noted $\mathbf{d}$
- Updated/benchmarked 2-stream model from Pinty et al. JGR (2006) noted $M(\mathbf{X})$
- A priori knowldege/guess on model parameters noted $\mathbf{X}_{prior}$

uncertainty on the RS products is specified in the measurement set covariance matrix $\mathbf{C}_d$

uncertainty associated the model parameter is specified via a covariance matrix $\mathbf{C}_{X_{prior}}$

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
- Posterior uncertainties on retrieved parameters are estimated from the curvature of $J(\mathbf{X})$

Pinty etal., (2007): Journal of Geophysical Research, *doi:10.129/2006JD008105*

OUTPUTS: posterior knowledge

- PDFs of all 2-stream model parameters:

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

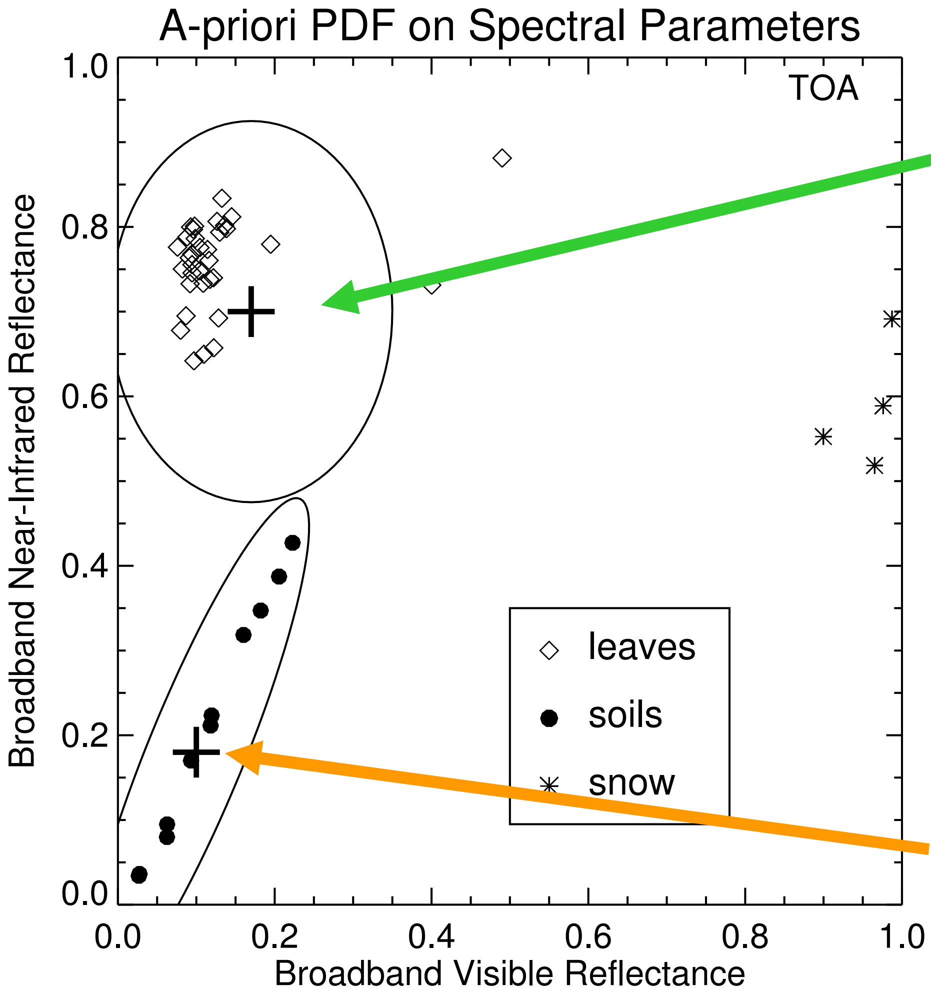
a posteriori uncertainty covariance matrix

- Assessement 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:10.129/2006JD008105*

prior knowledge on model parameters



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

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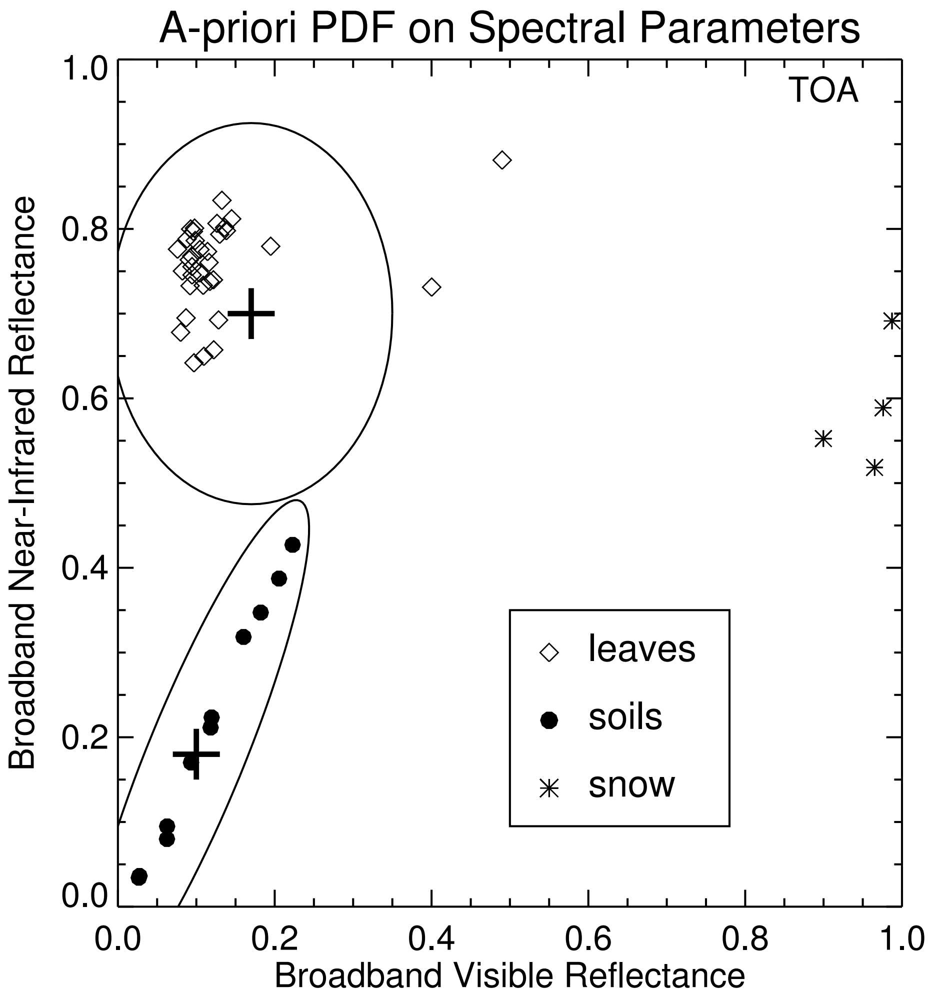

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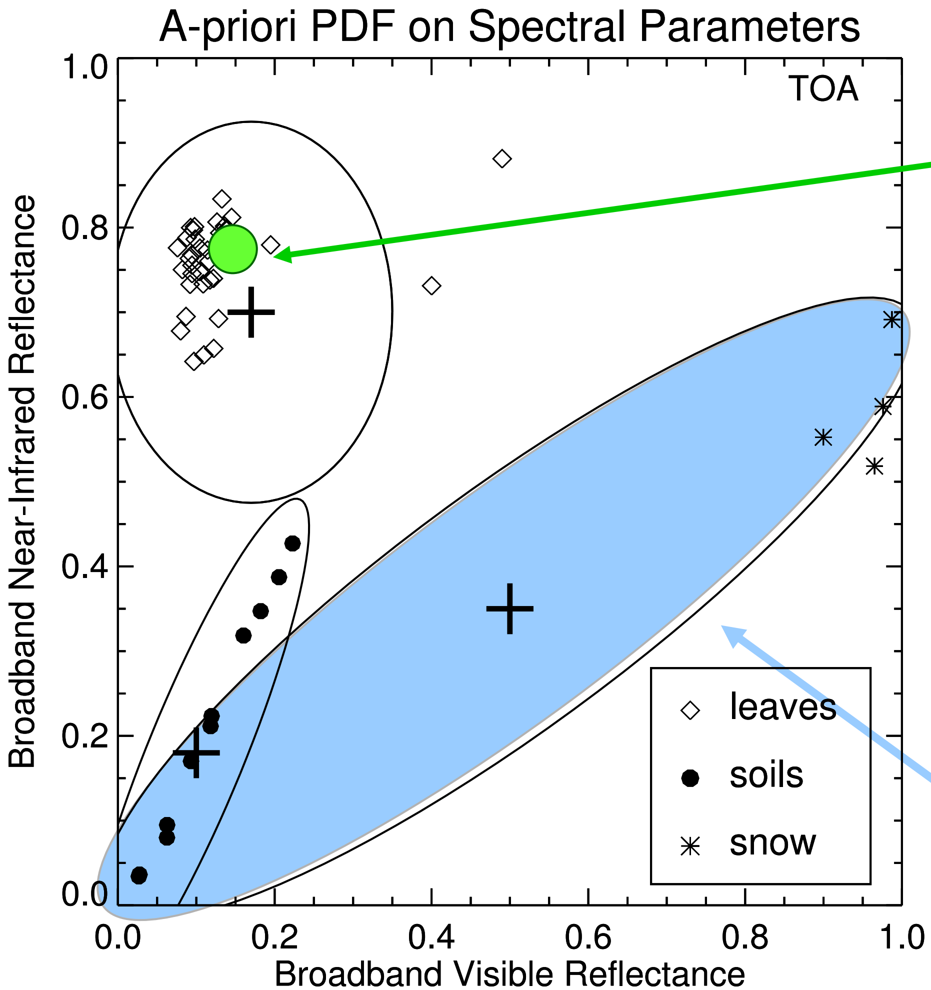

a priori 'green' leaves

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in case snow occurs

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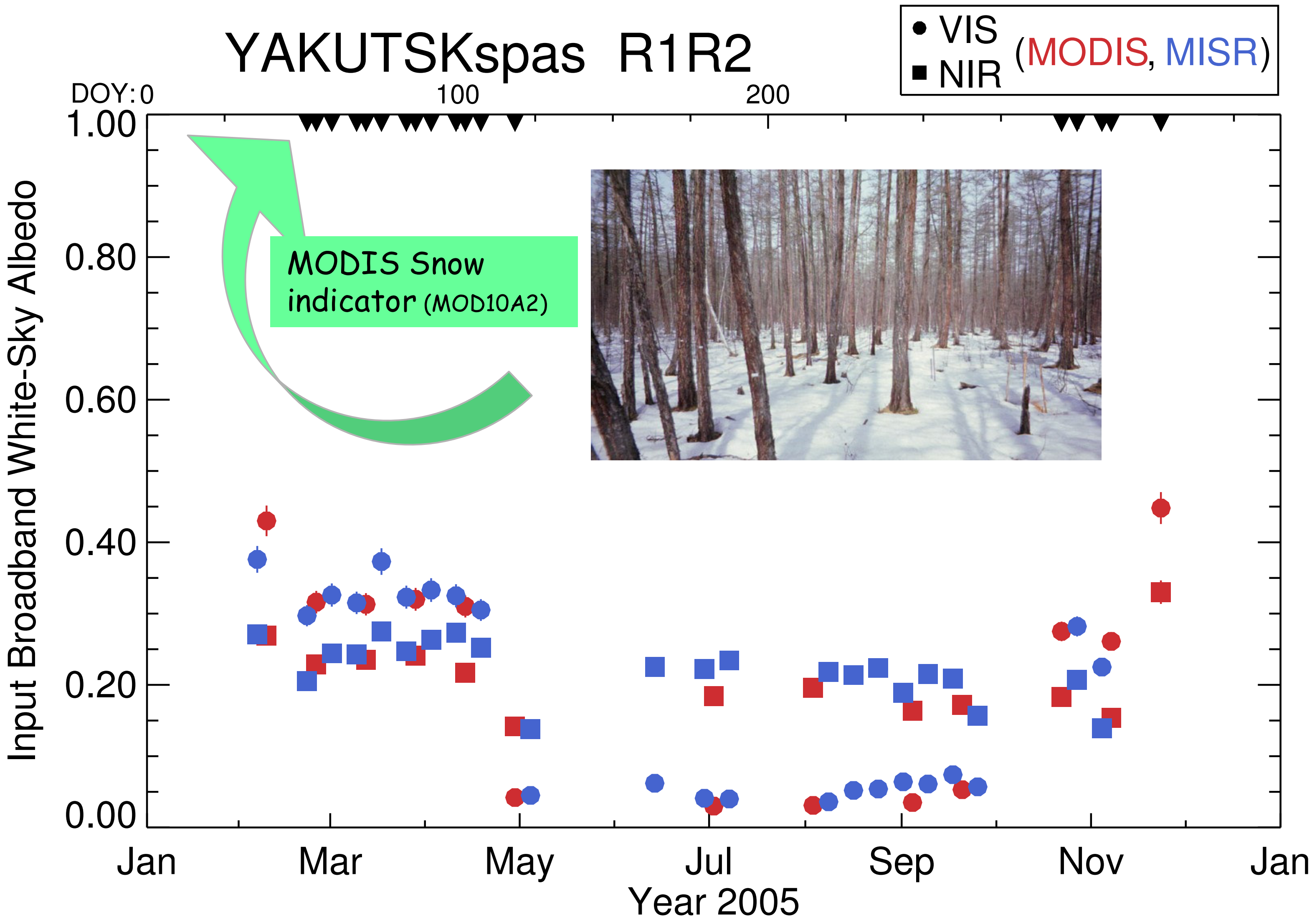
Application over Yakustk Forest: a deciduous needle-leaf larch forest

Application over Yakutsk: Measurements



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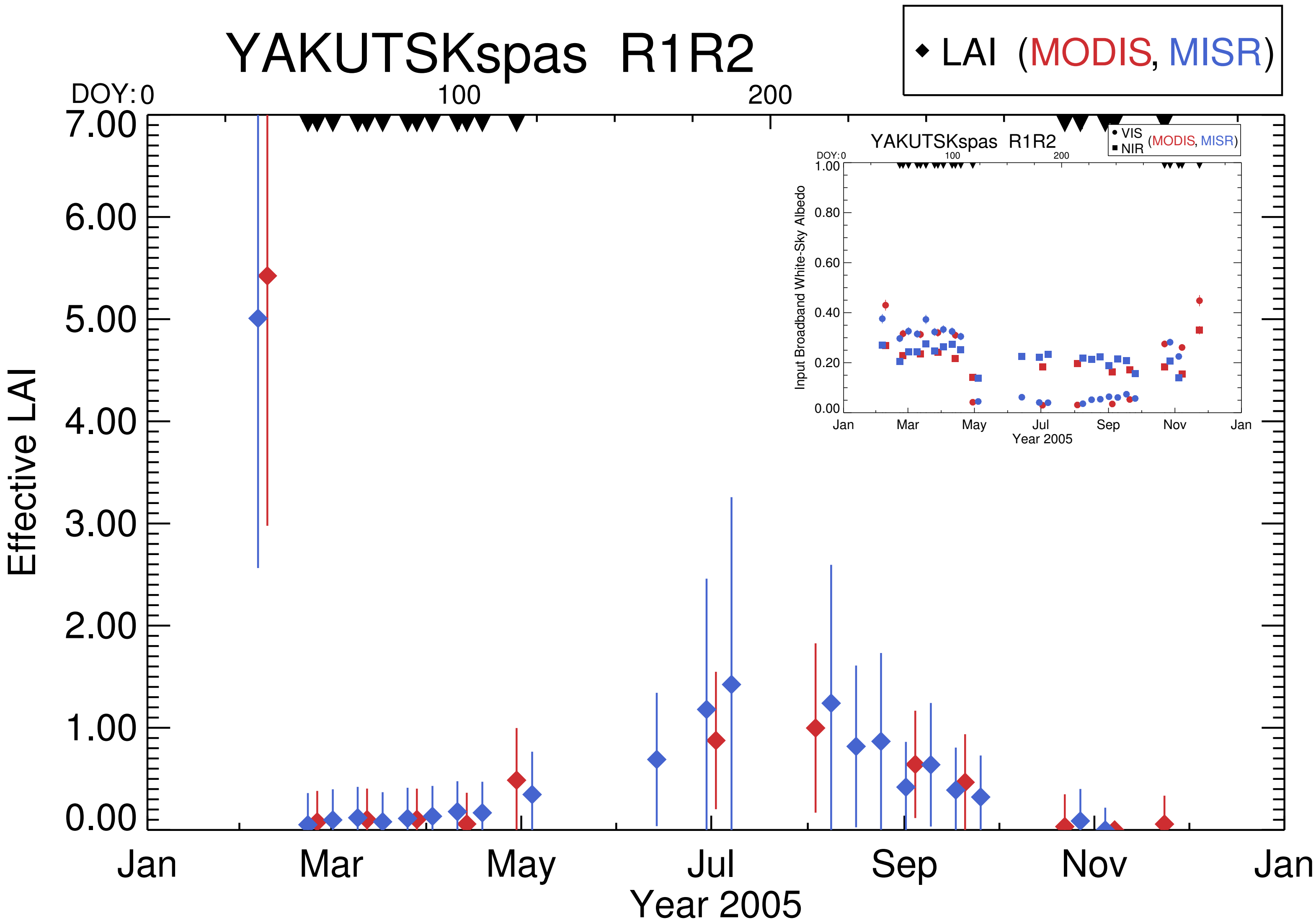

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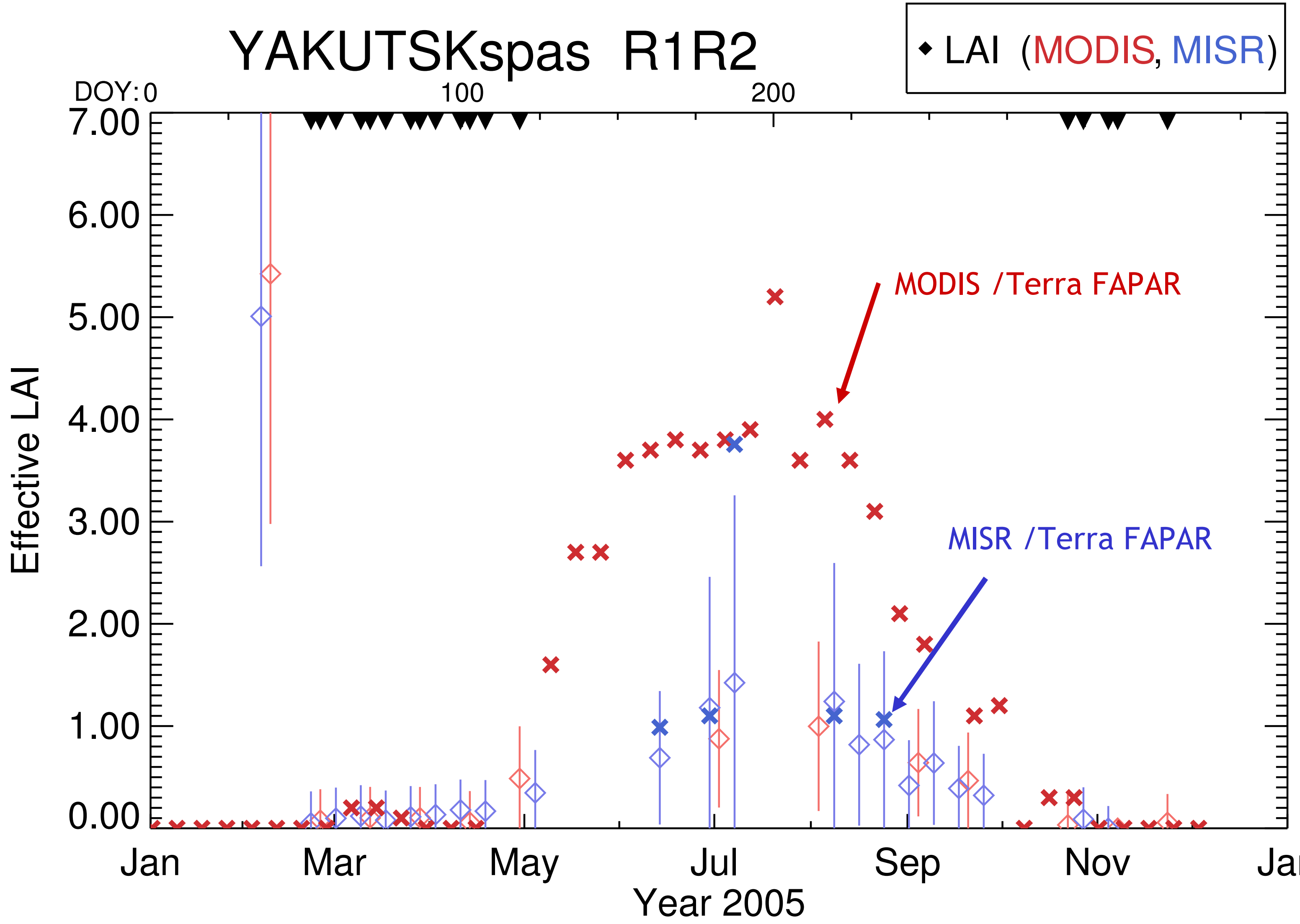

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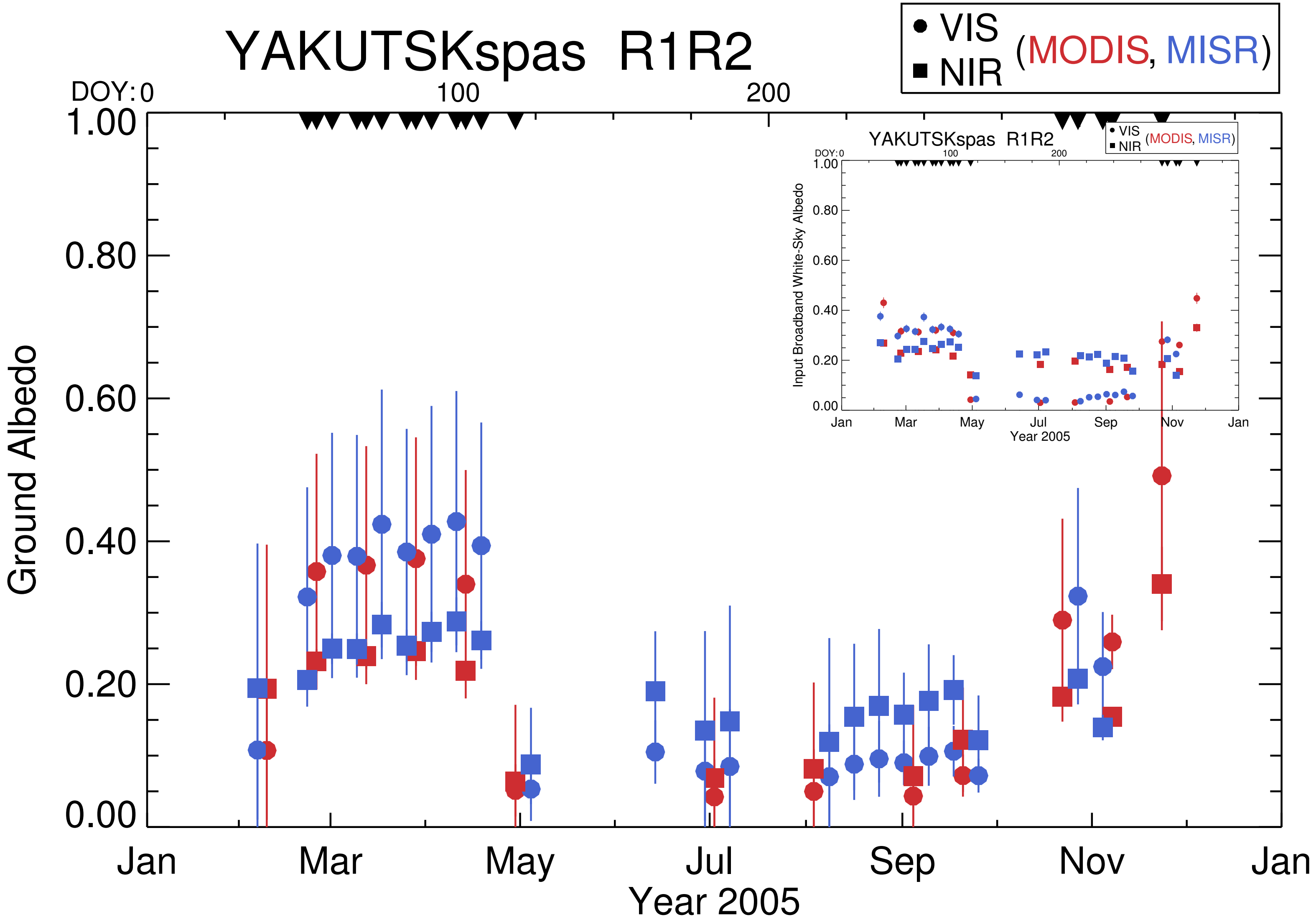

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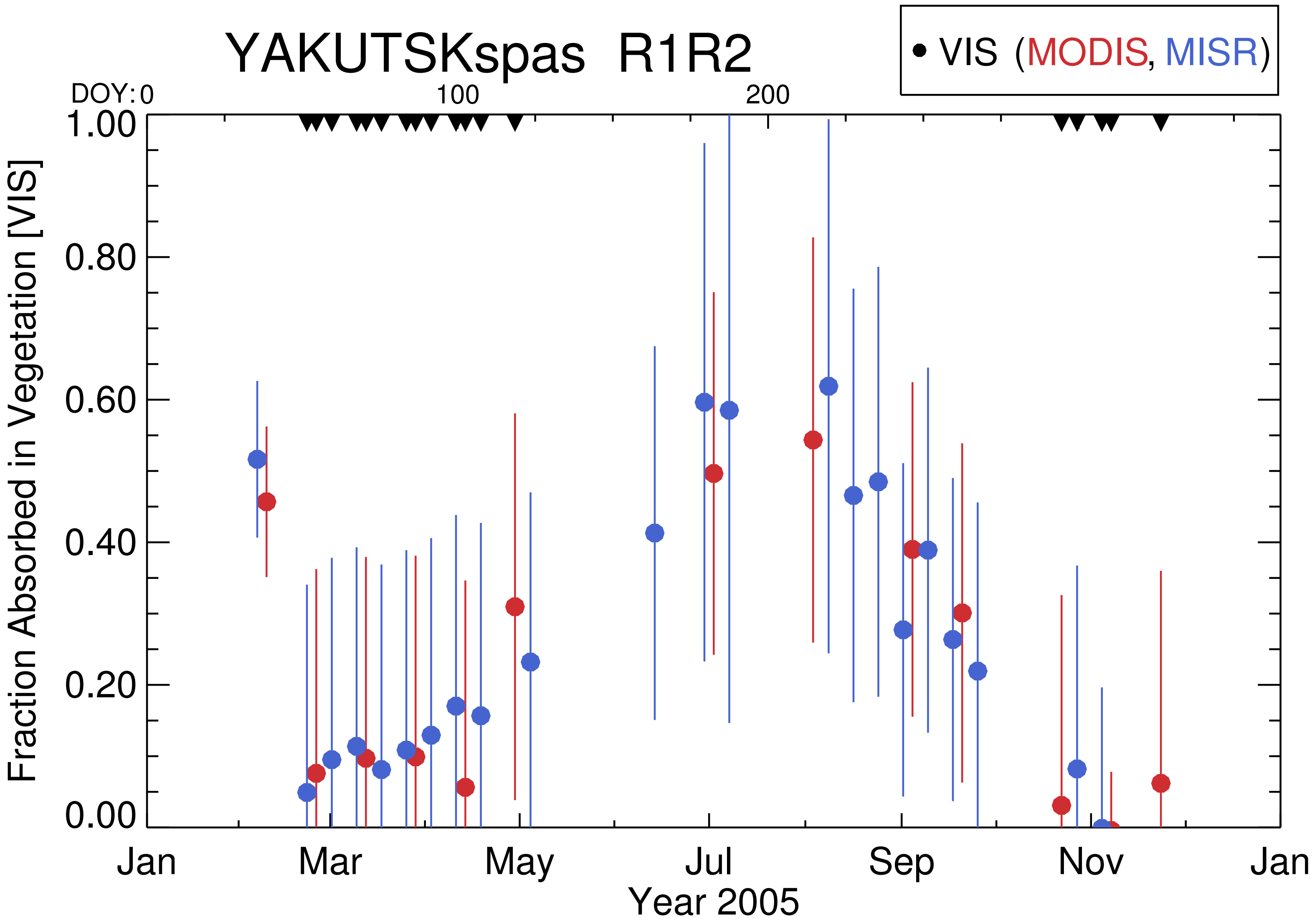

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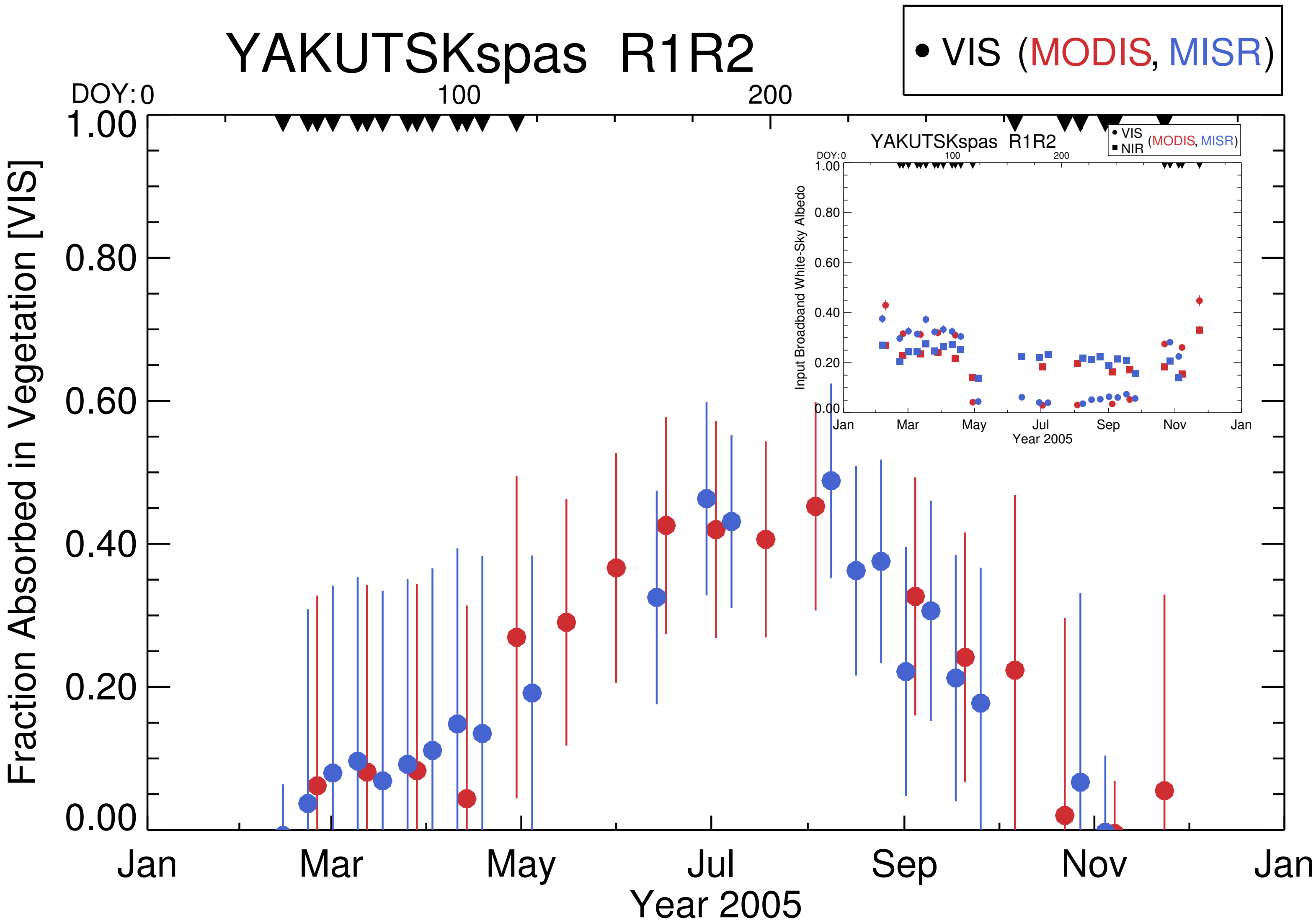

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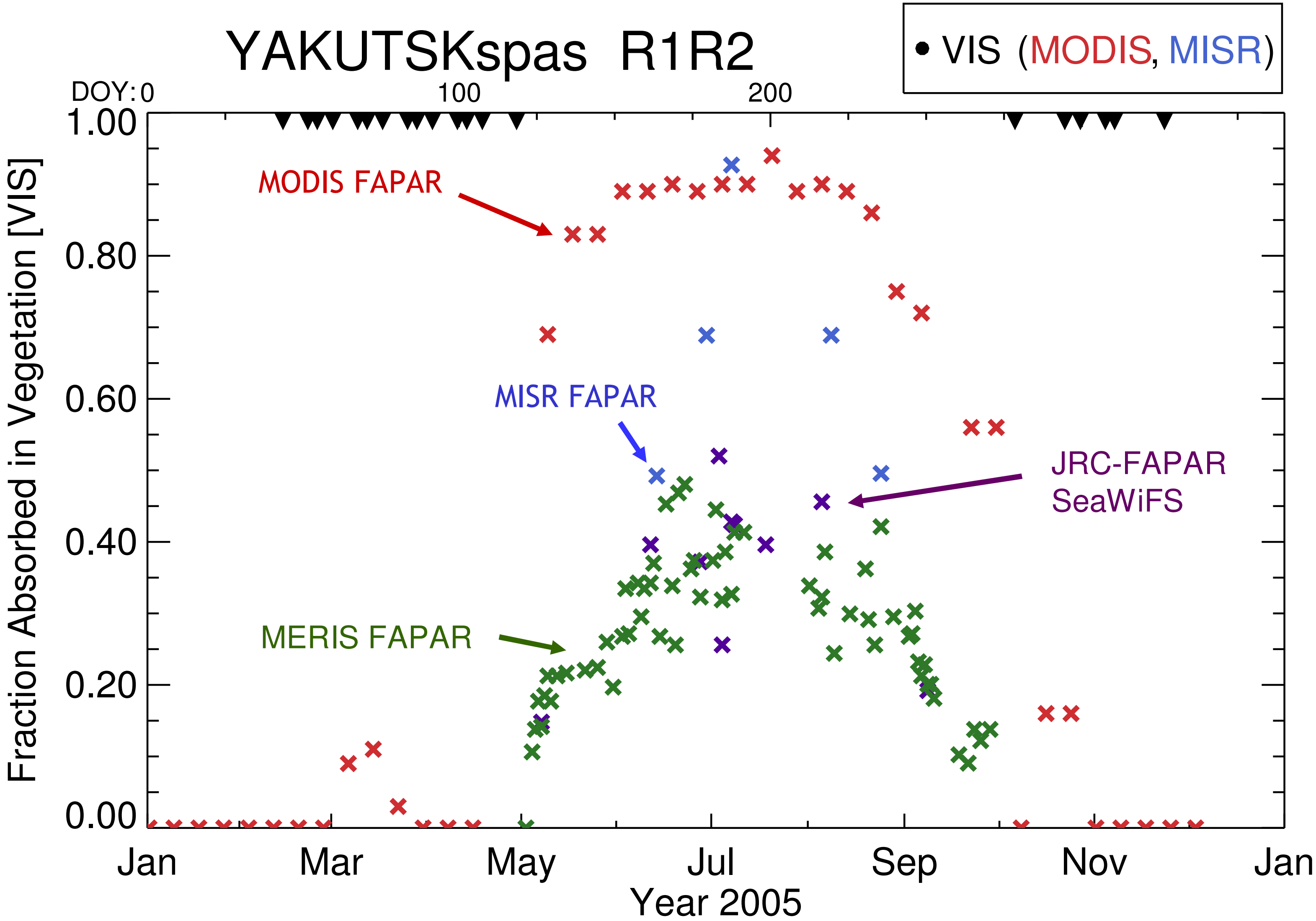

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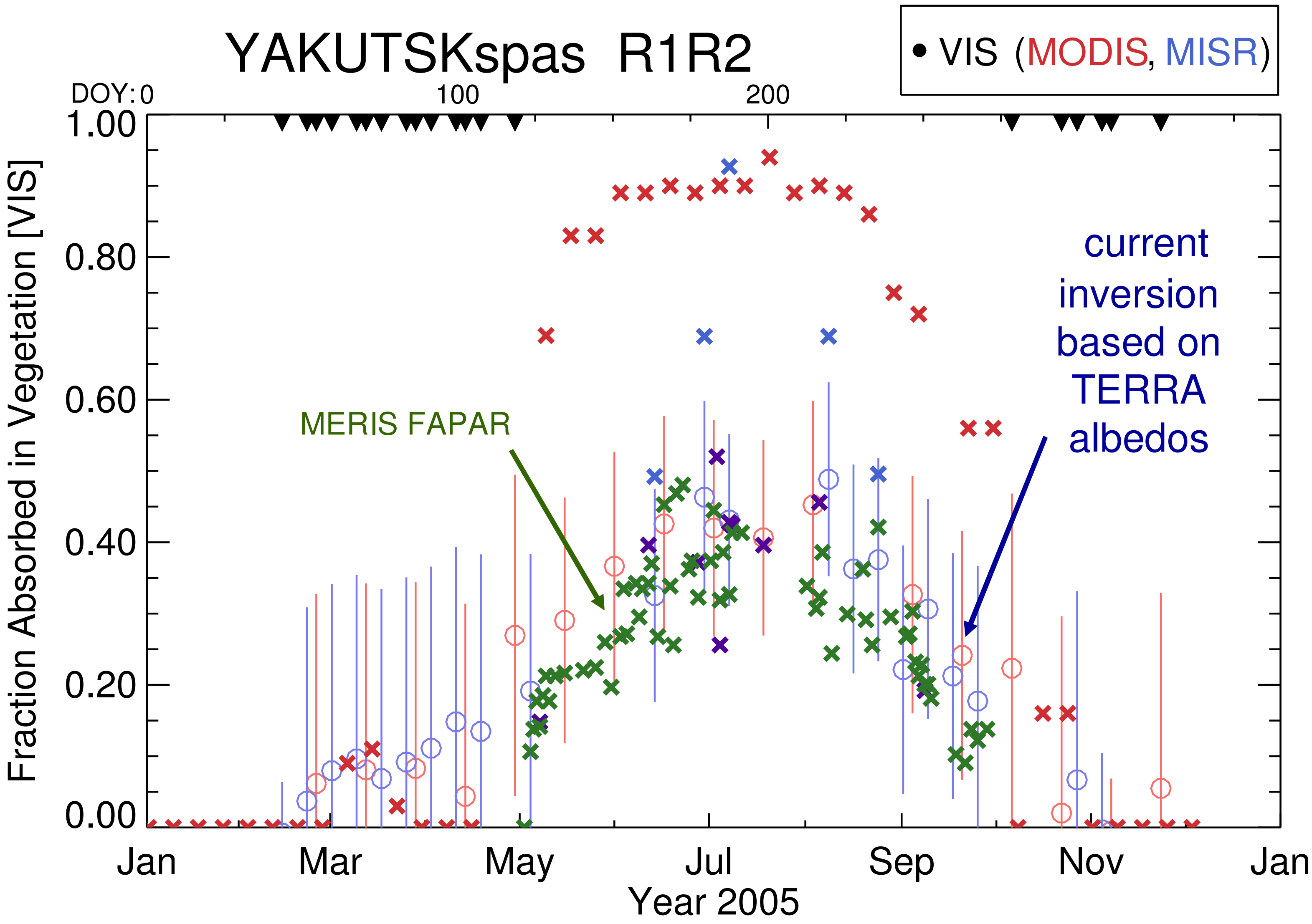

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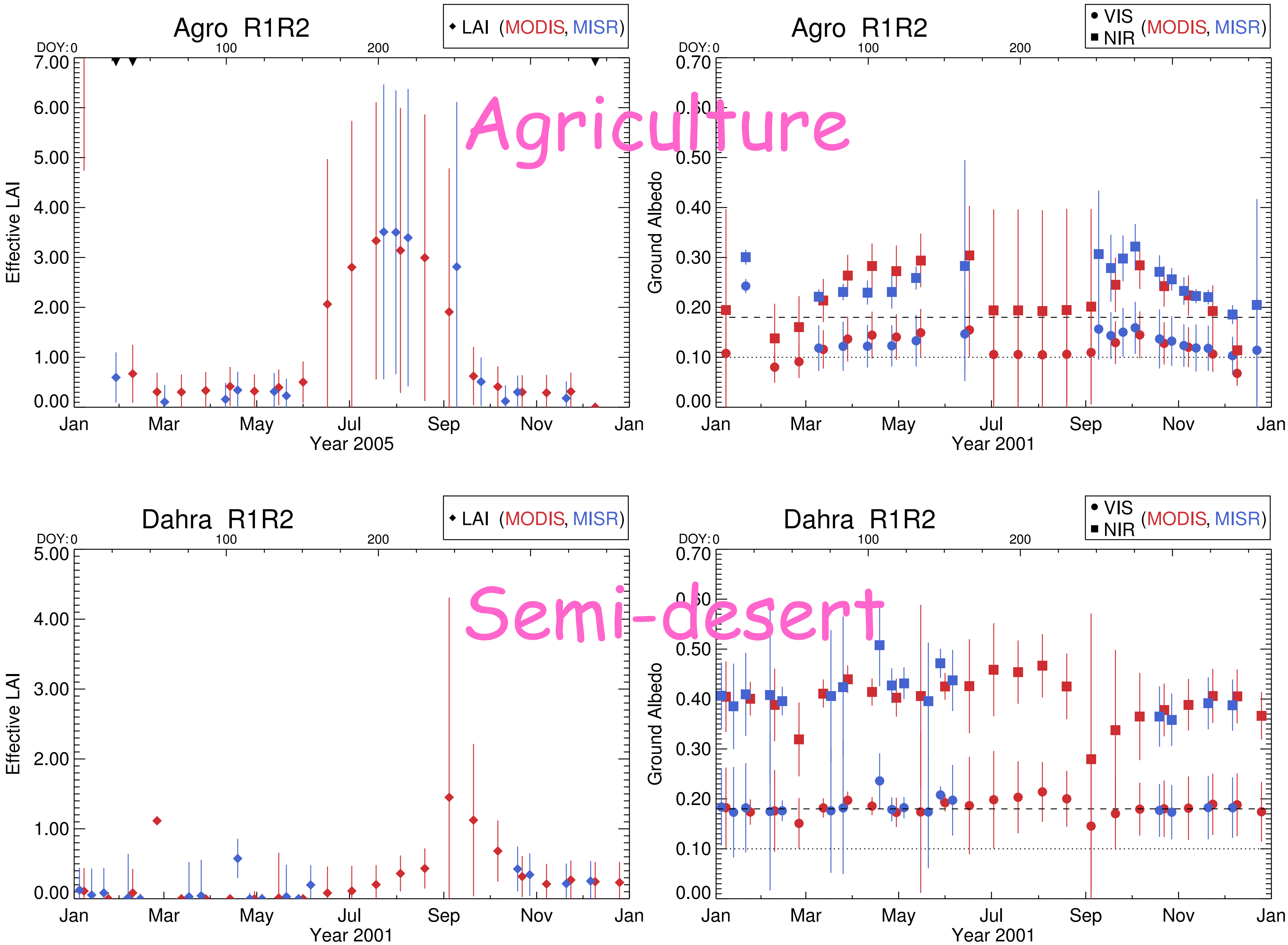
Agro R1R2
LAI (MODIS, MISR)
VIS
NIR (MODIS, MISR)
Agriculture
Effective LAI
Ground Albedo
DOY: 0
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Dahra R1R2
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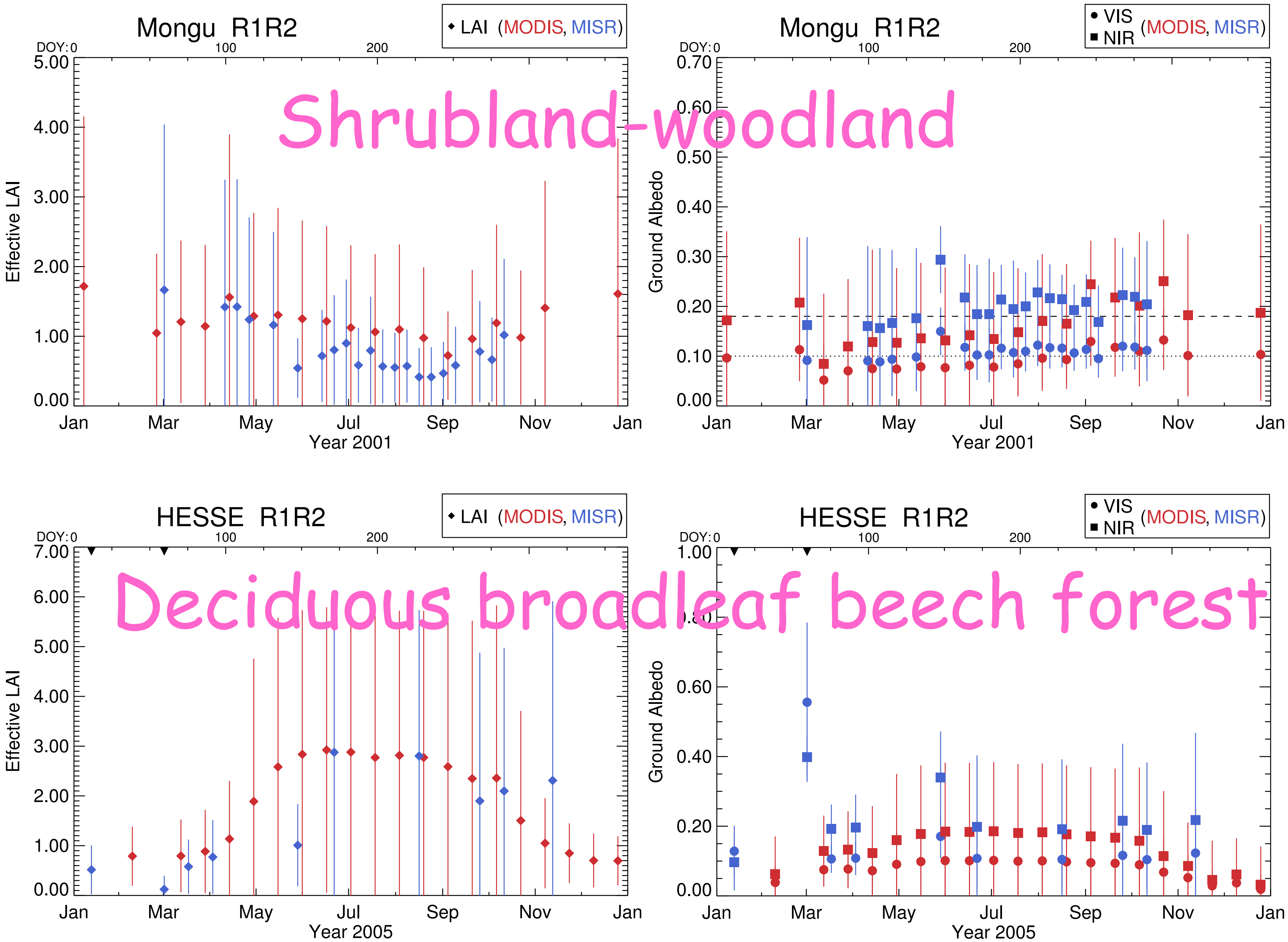
Year 2001



Mongu R1R2
LAI (MODIS, MISR)
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Effective LAI
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Mongu R1R2
VIS
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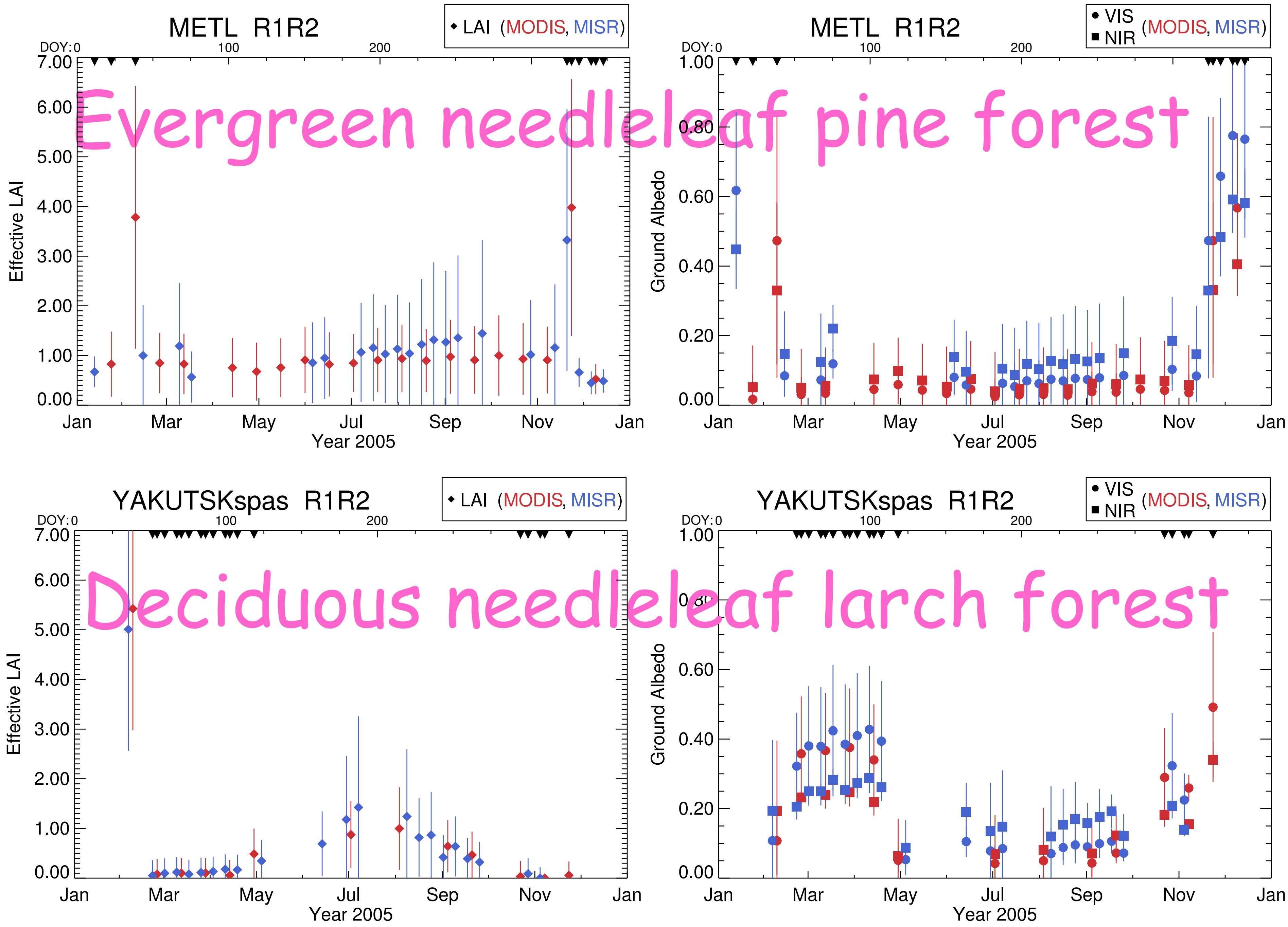
(MODIS, MISR)
Ground Albedo
Year 2001
Shrubland-woodland
HESSE R1R2
LAI (MODIS, MISR)
Effective LAI
Year 2005
HESSE R1R2
VIS
NIR
(MODIS, MISR)
Ground Albedo
Year 2005
Deciduous broadleaf beech forest
Jan Mar May Jul Sep Nov Jan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Ground Albedo
Year 2005
Evergreen needleleaf pine forest
YAKUTSKspas R1R2
LAI (MODIS, MISR)
Effective LAI
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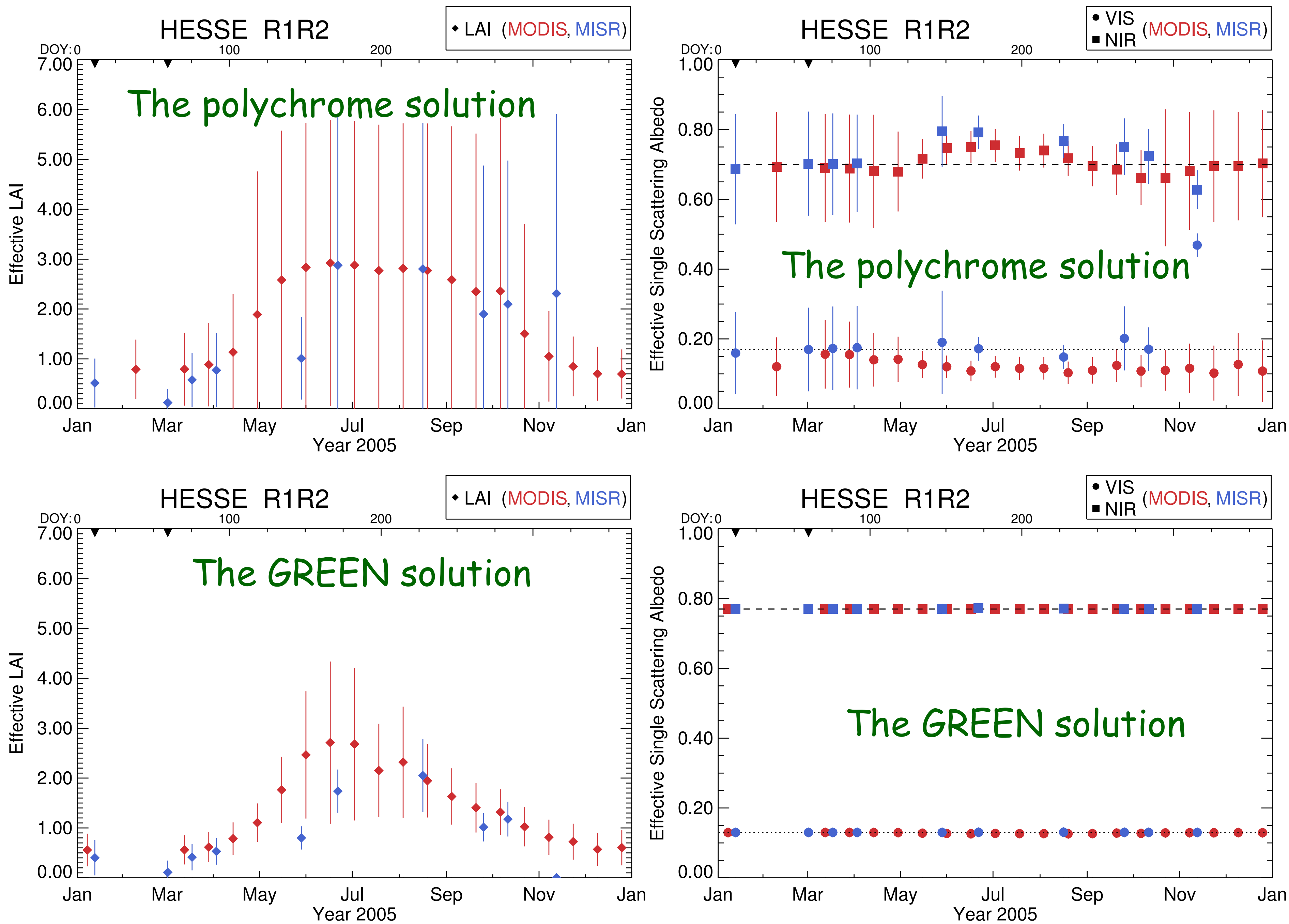
Deciduous needleleaf larch forest


HESSE R1R2
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Effective LAI
The polychrome solution
Jan
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Year 2005
HESSE R1R2
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NIR
(MODIS, MISR)
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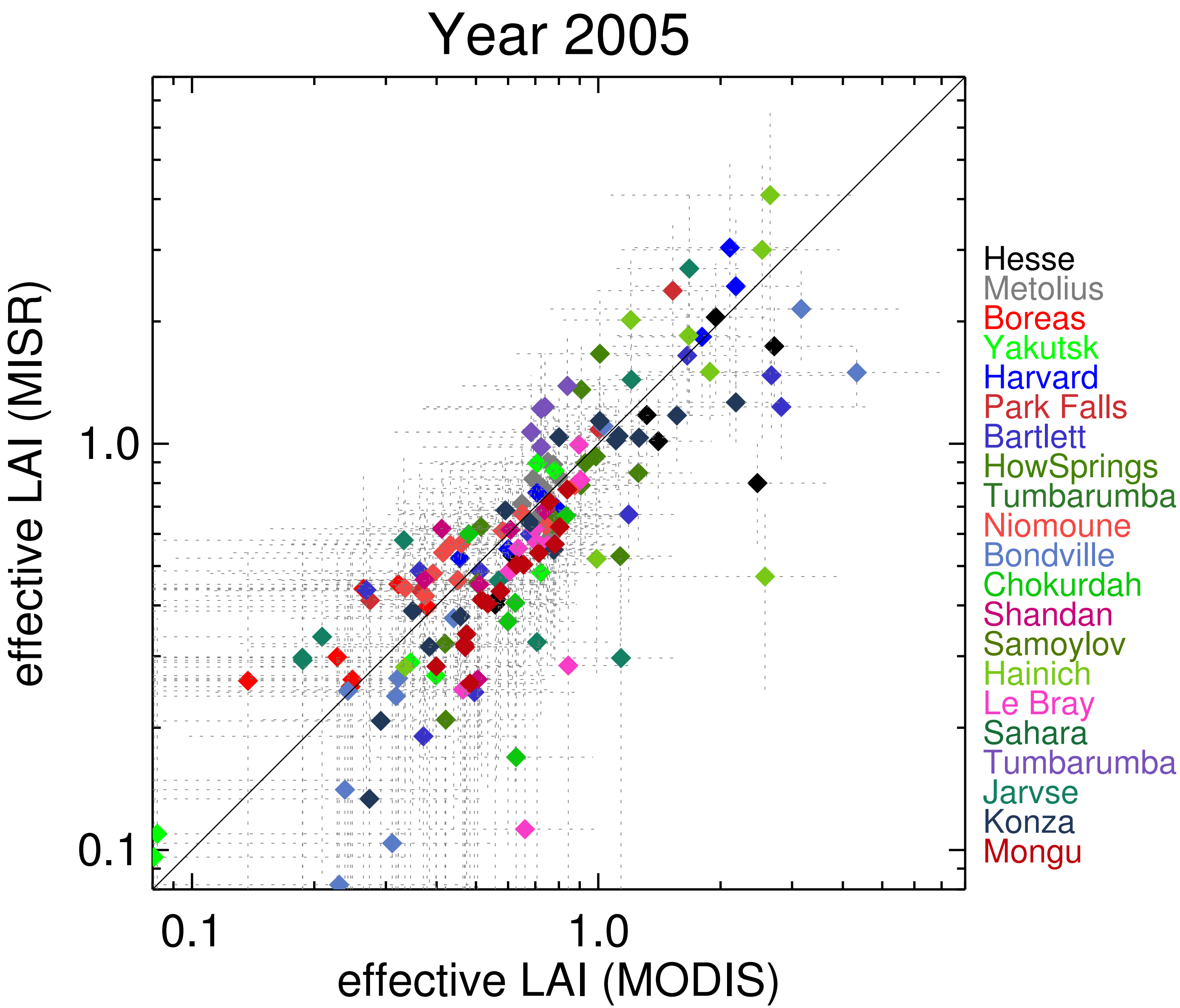
0.60
0.40
0.20
0.00
Effective Single Scattering Albedo
The polychrome solution
HESSE R1R2
LAI (MODIS, MISR)
The GREEN solution
HESSE R1R2
VIS
NIR
(MODIS, MISR)
The GREEN solution

Statistics over FIFE – like sites



a priori 'green' leaves

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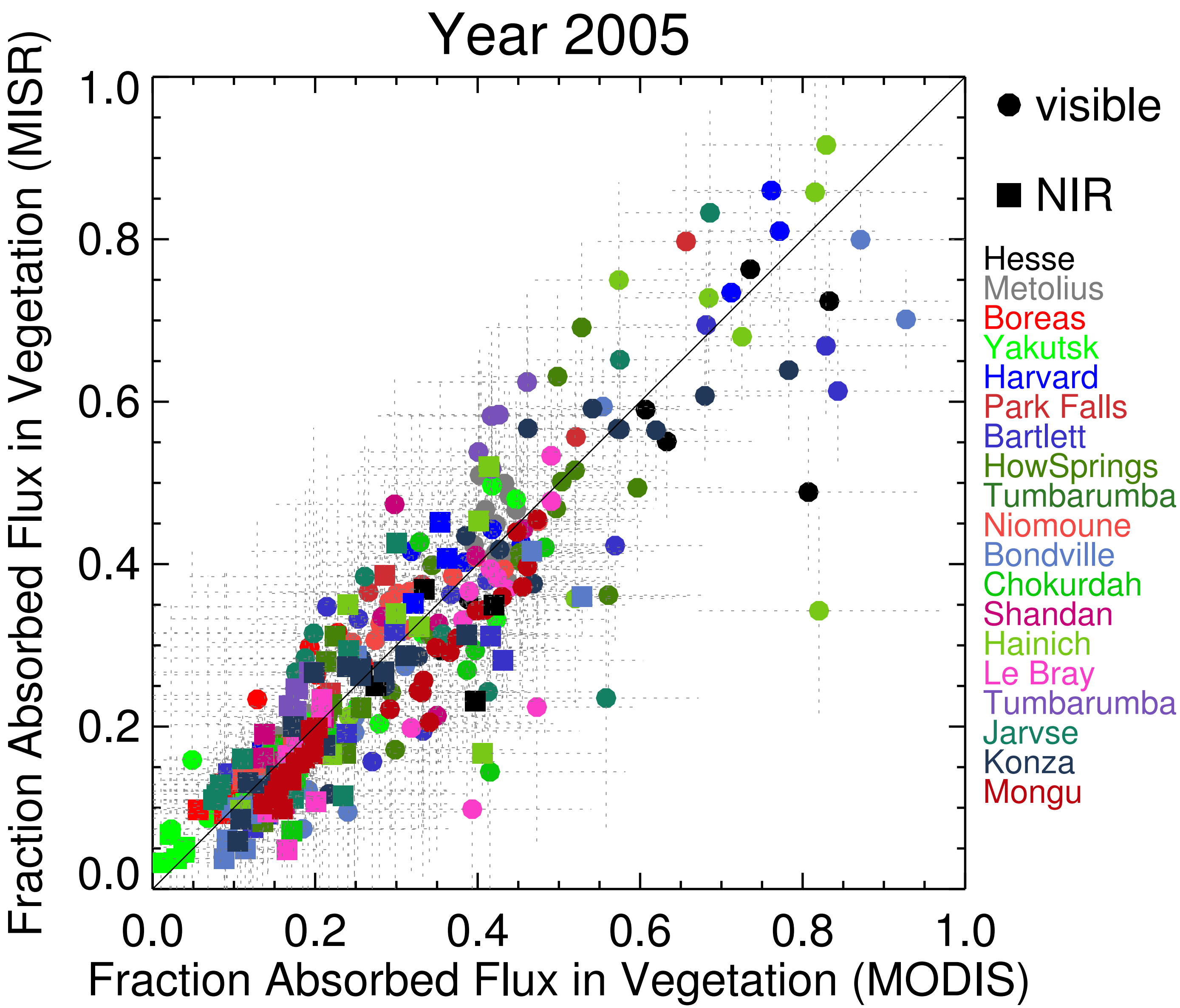

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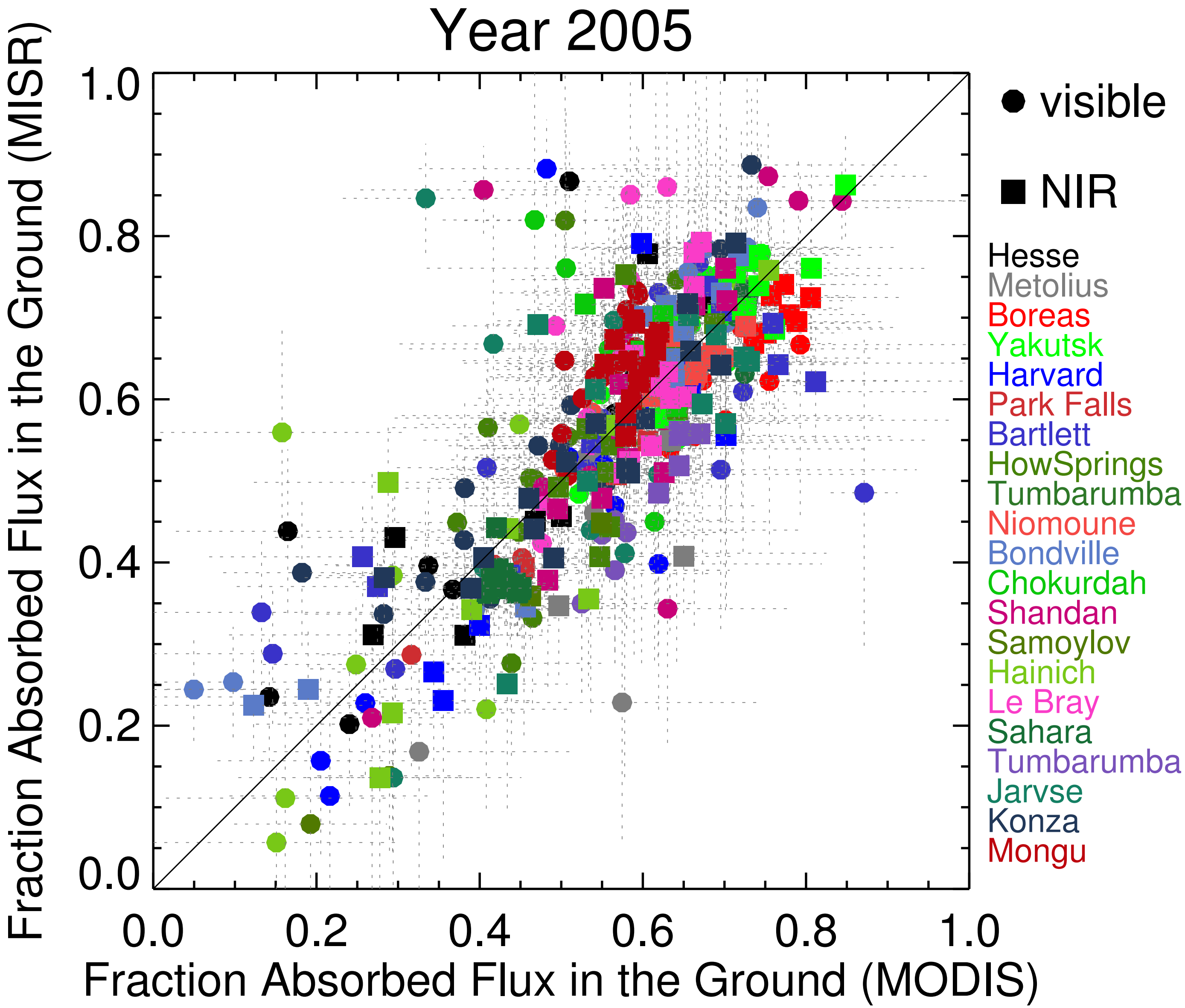

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Concluding remarks

1. Computer efficient inversion package has been designed and tested : estimate of uncertainty on all retrievals

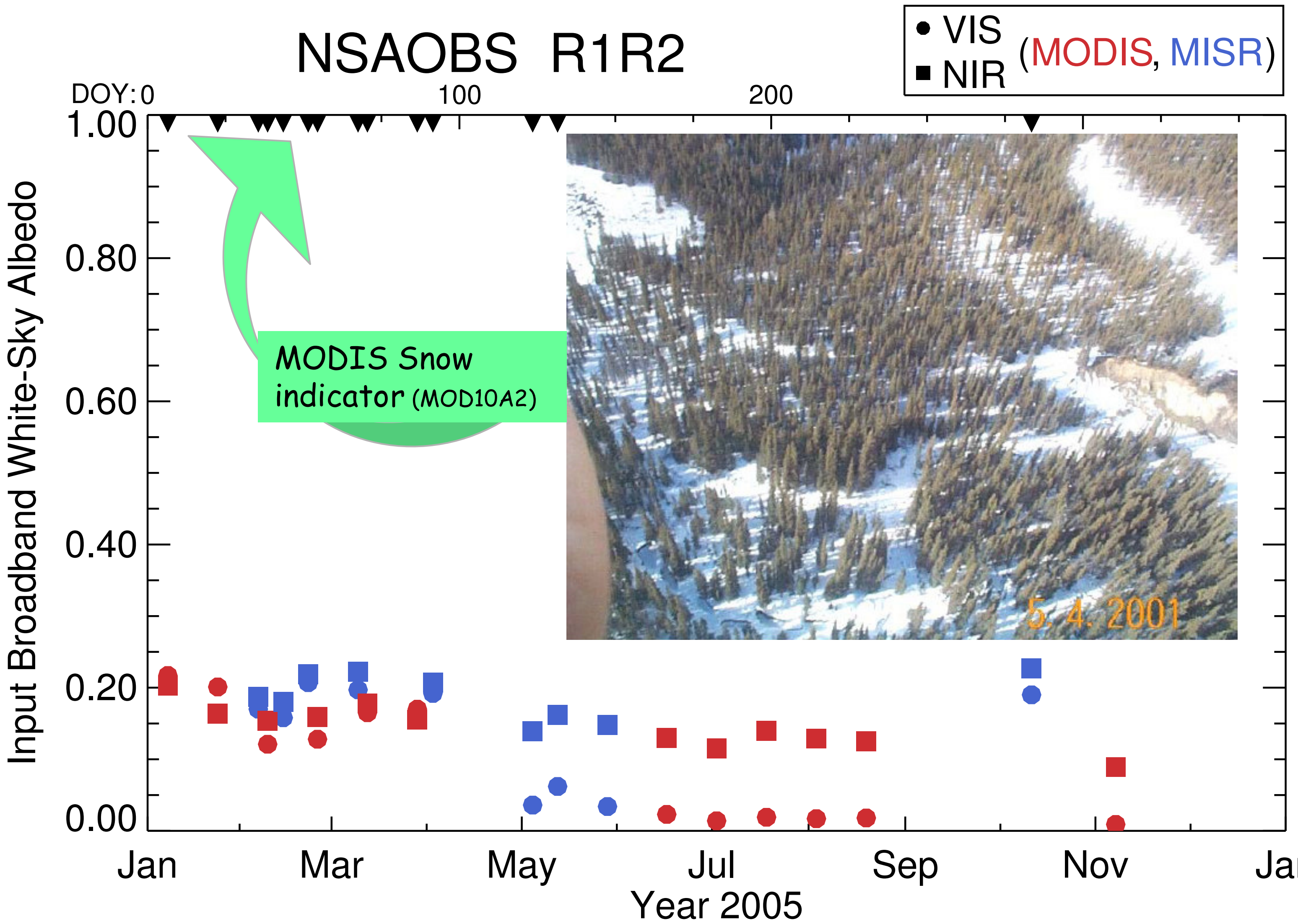
2. This integrated package can be used for various purposes : retrieval of parameters from RS products, validation of RS products, assimilation of RS products into Land surface schemes.

3. Capability to generate global surface model parameters ensuring full consistency with measured (uncorrelated) fluxes from various sources: spectral albedos from MODIS-MISR (and any other sources).

4. Estimating radiant fluxes and surface parameters in the presence of snow .

Application over BOREAS NSA-OBS

Application over BOREAS: Measurements



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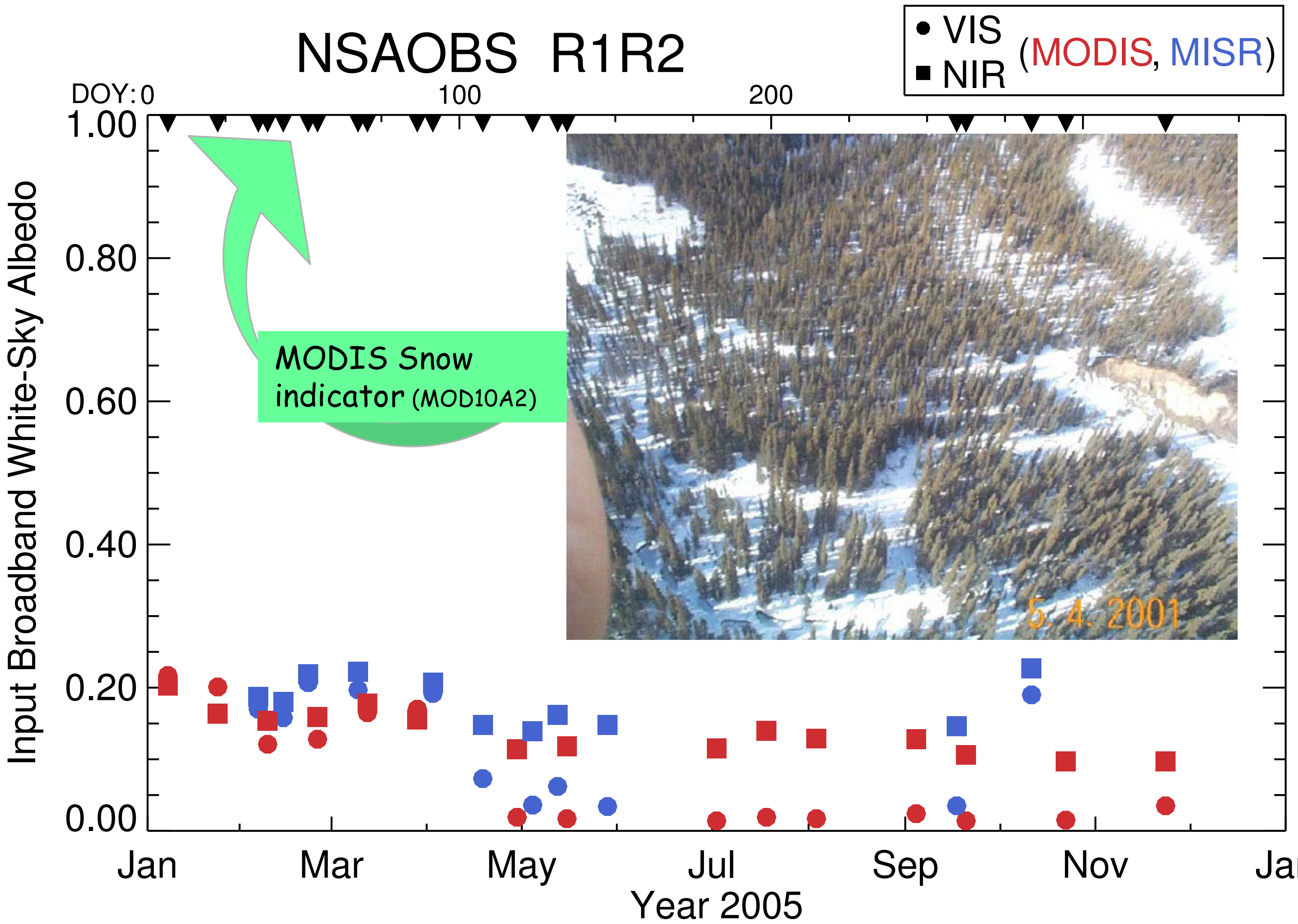

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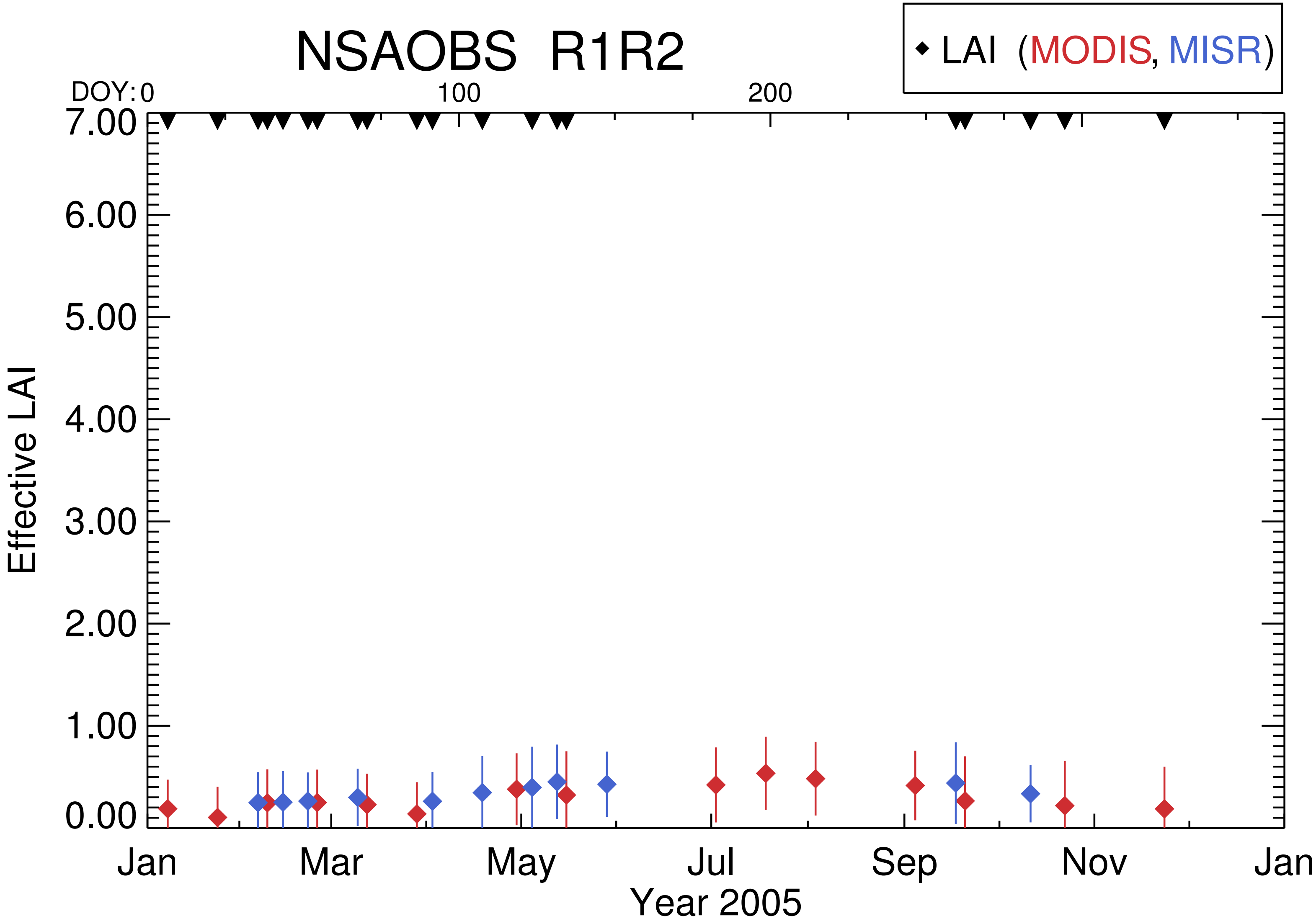

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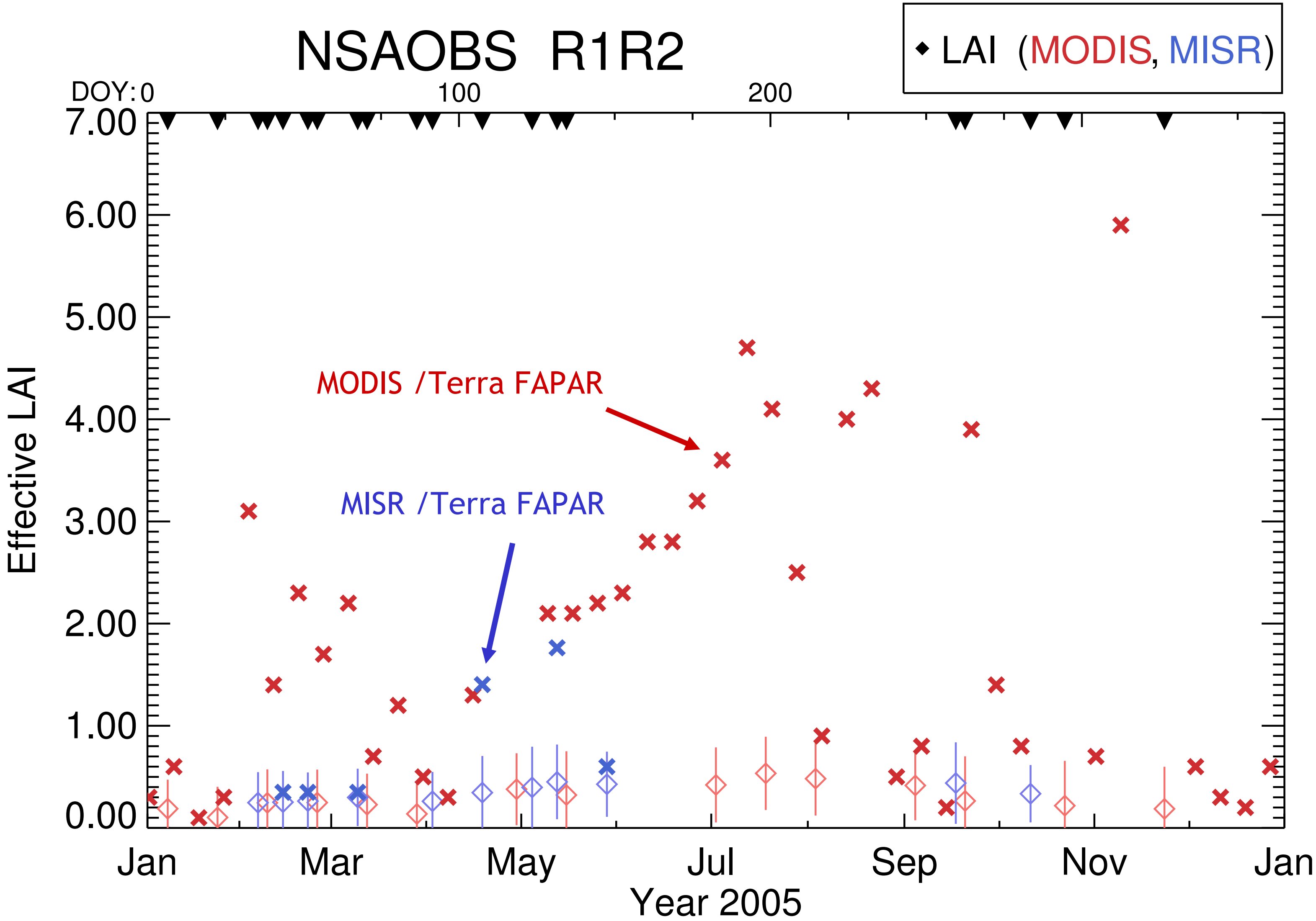

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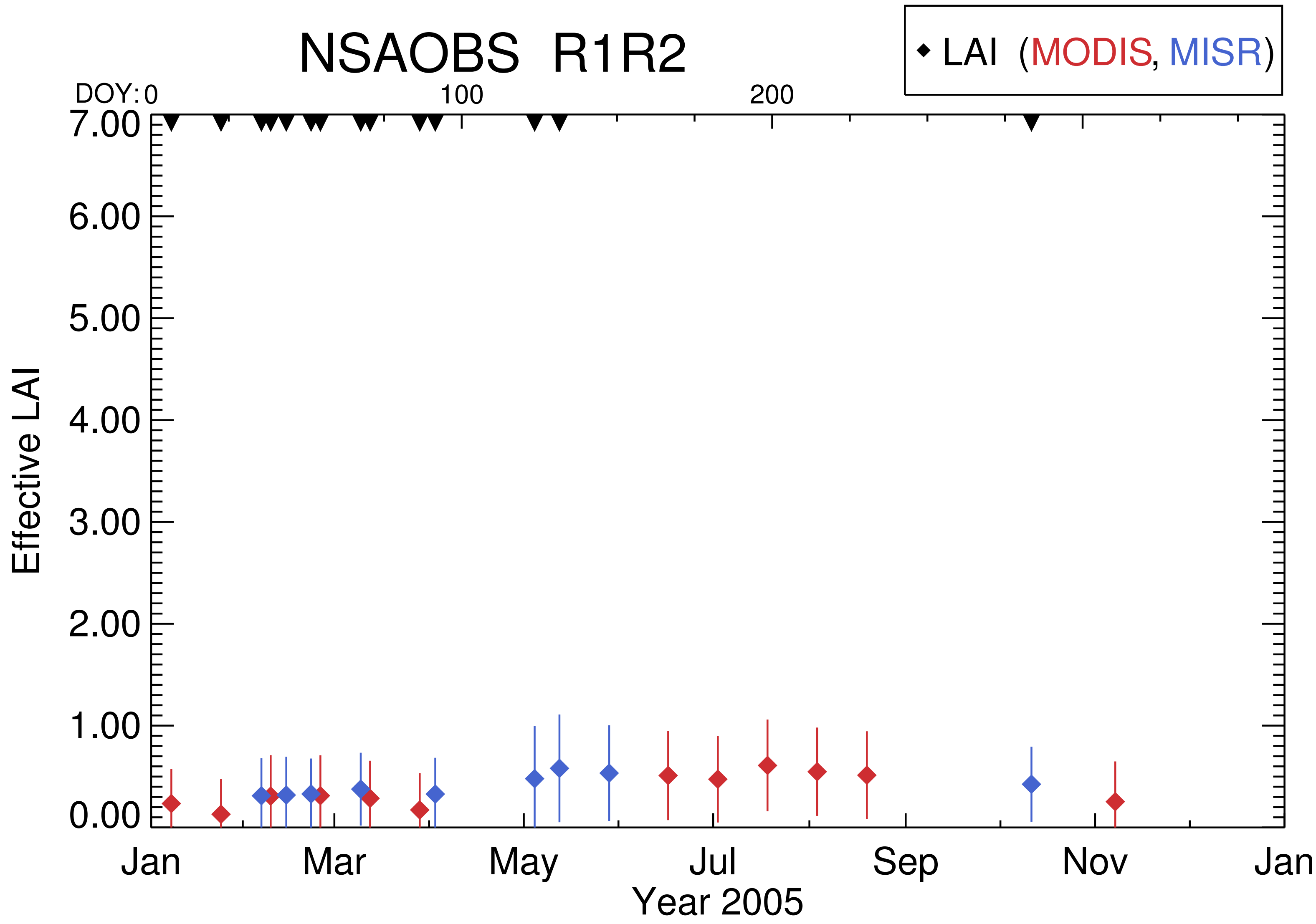

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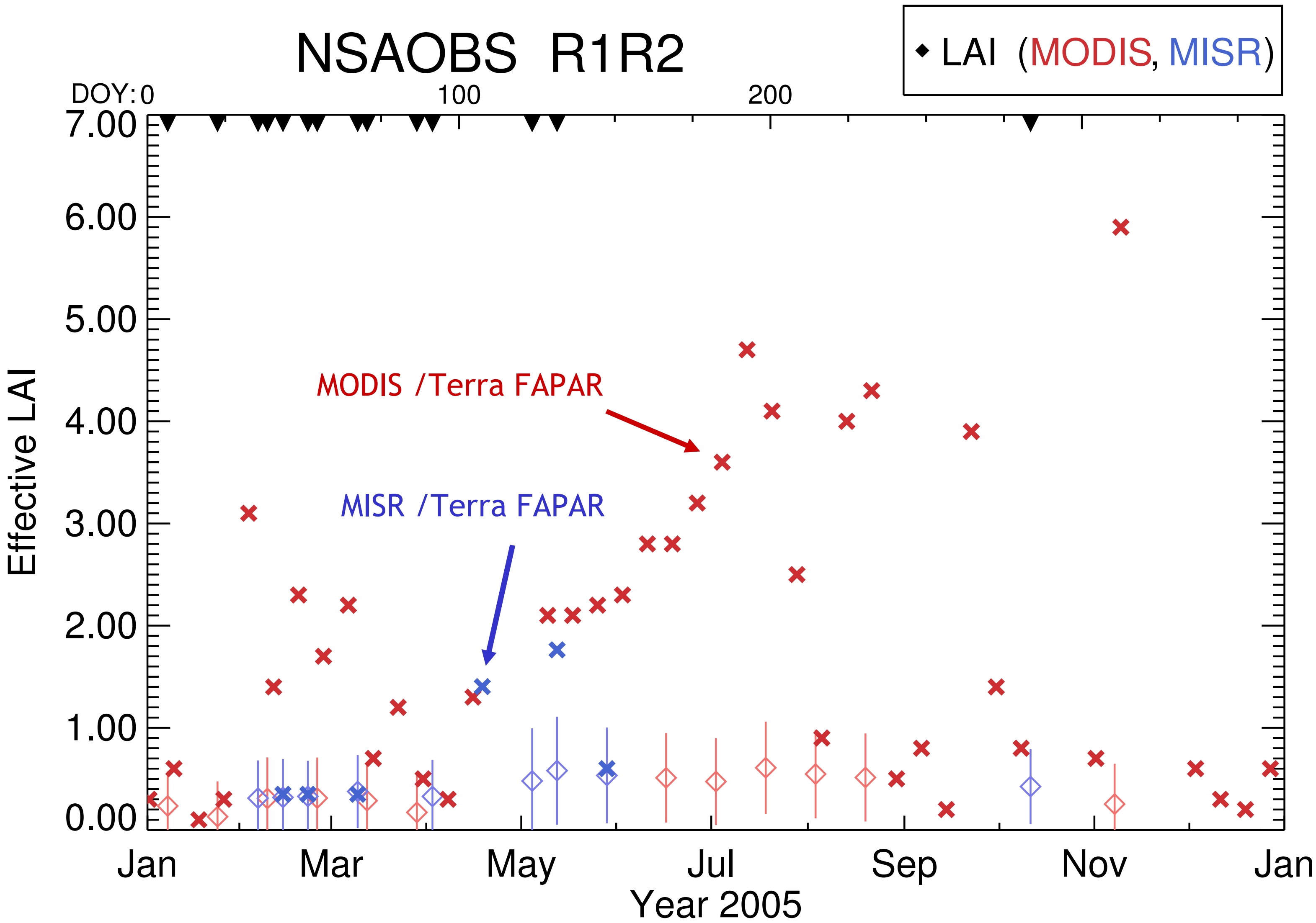

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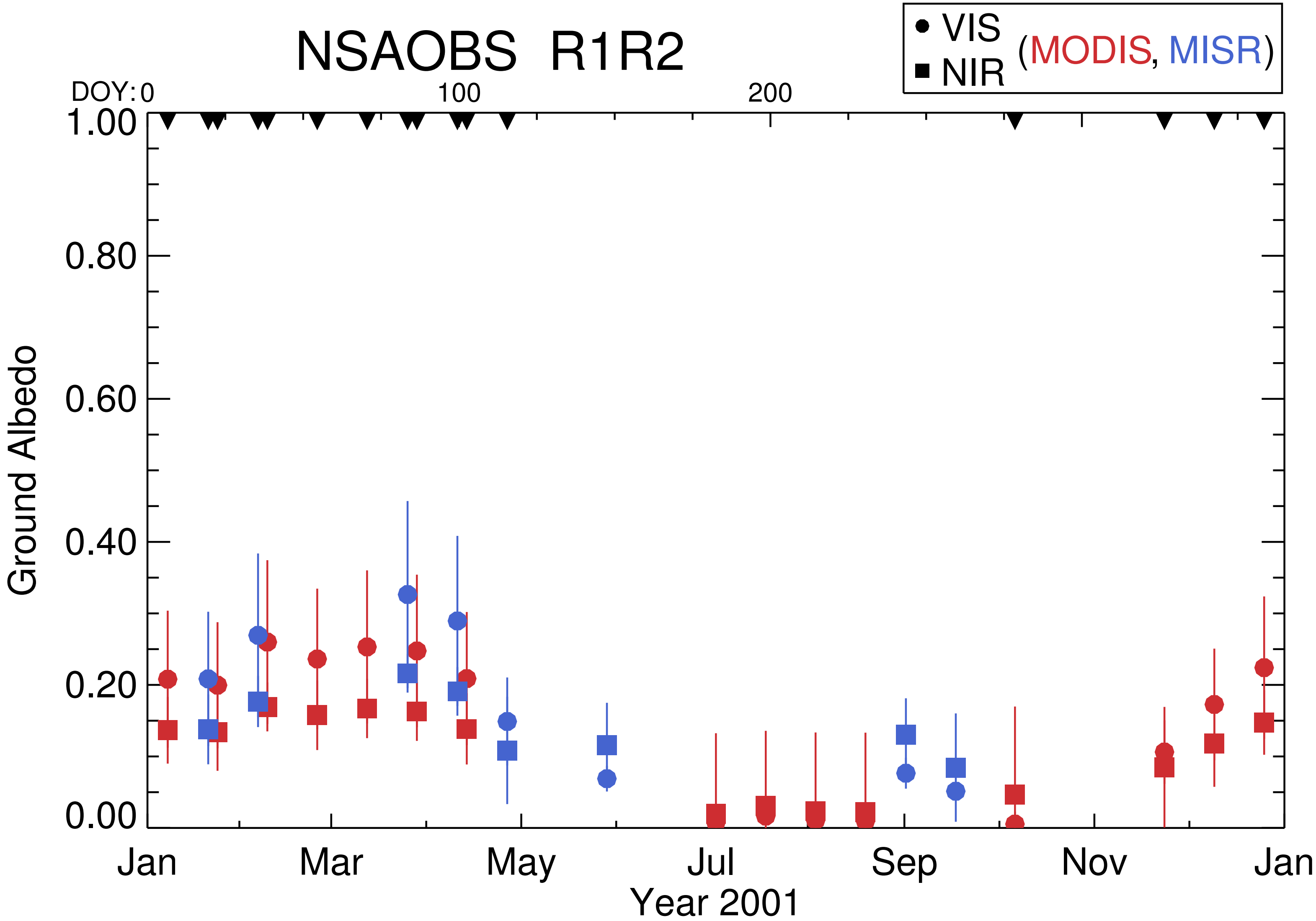

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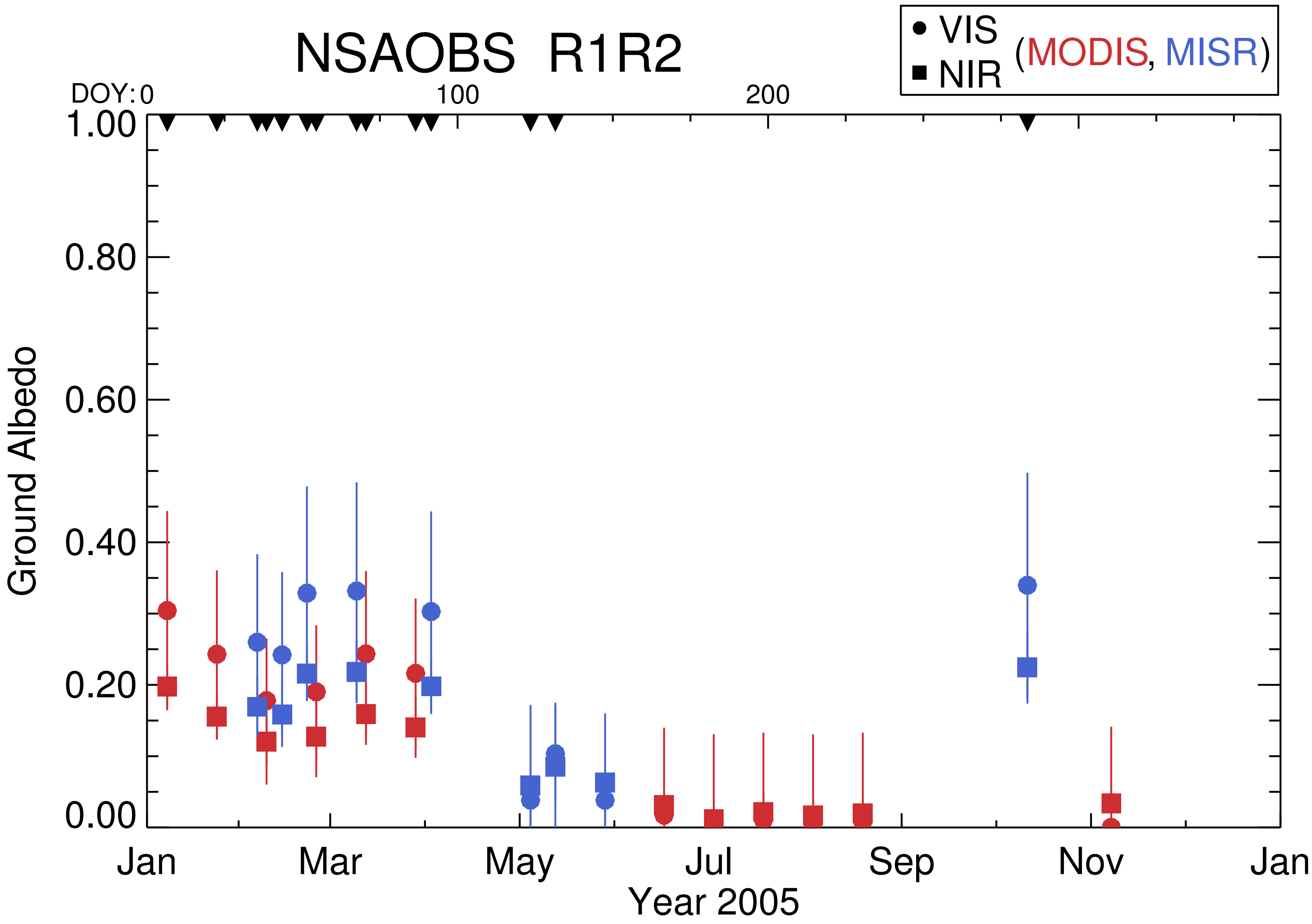
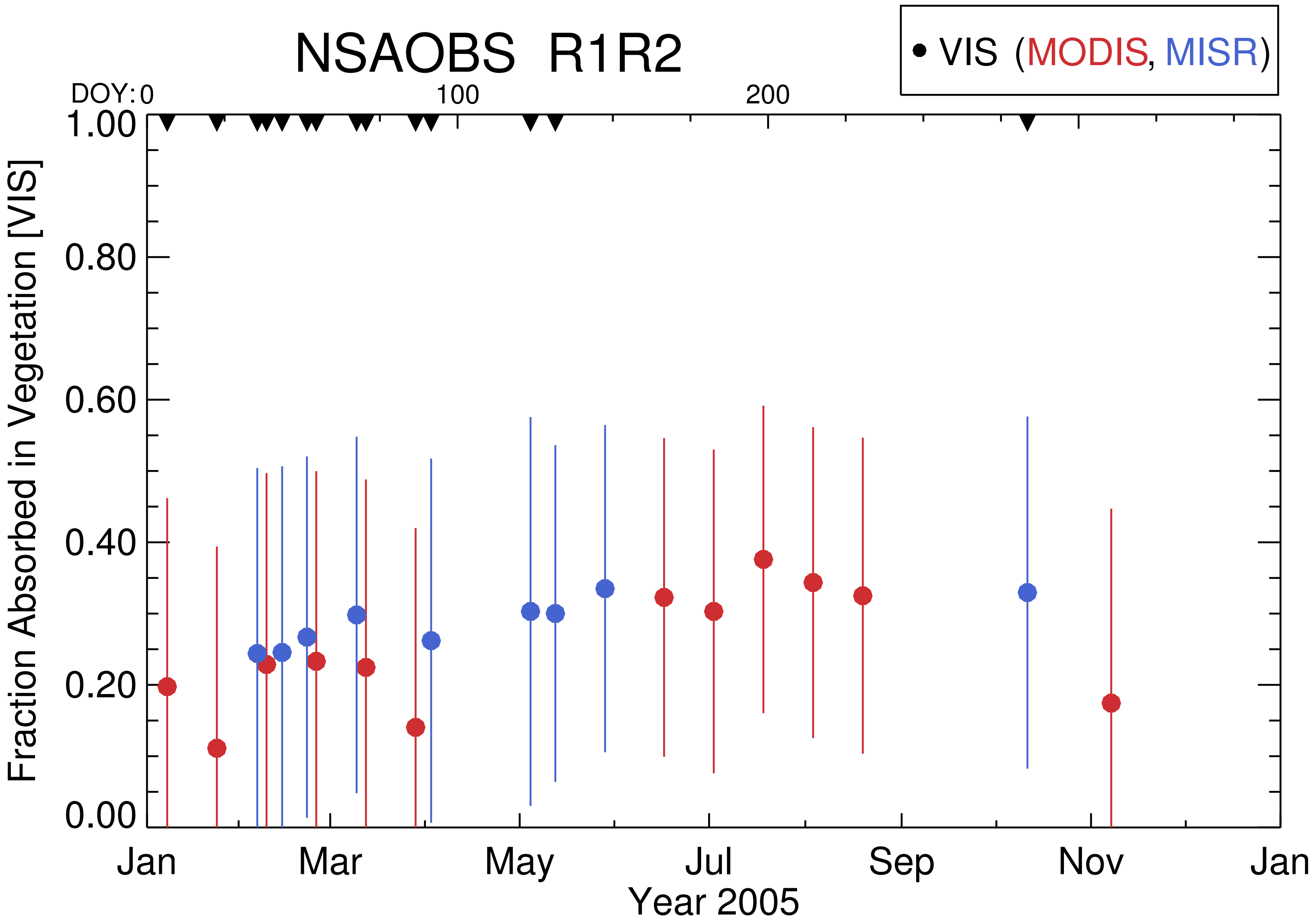
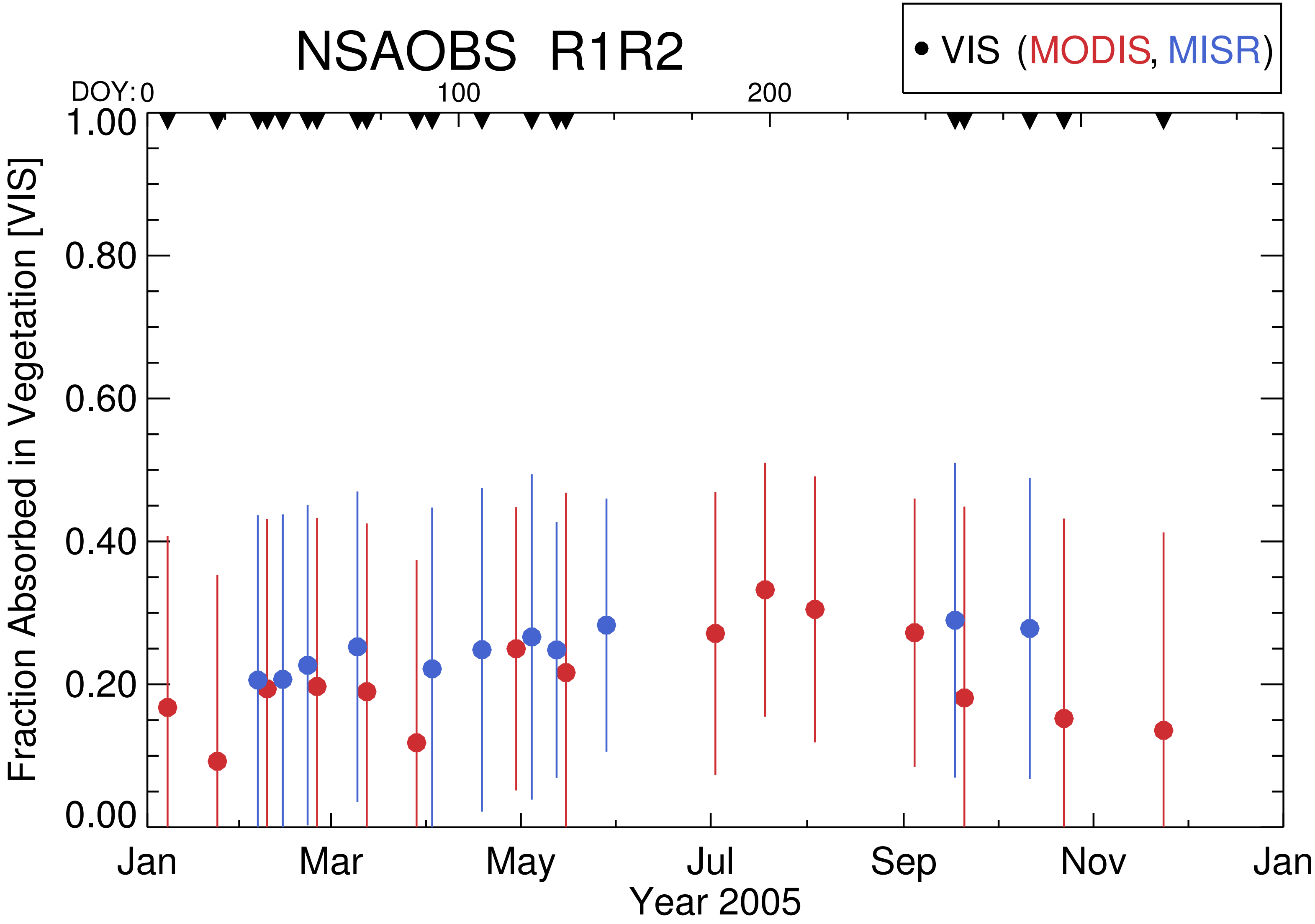


Application over NSAOBS: radiant fluxes

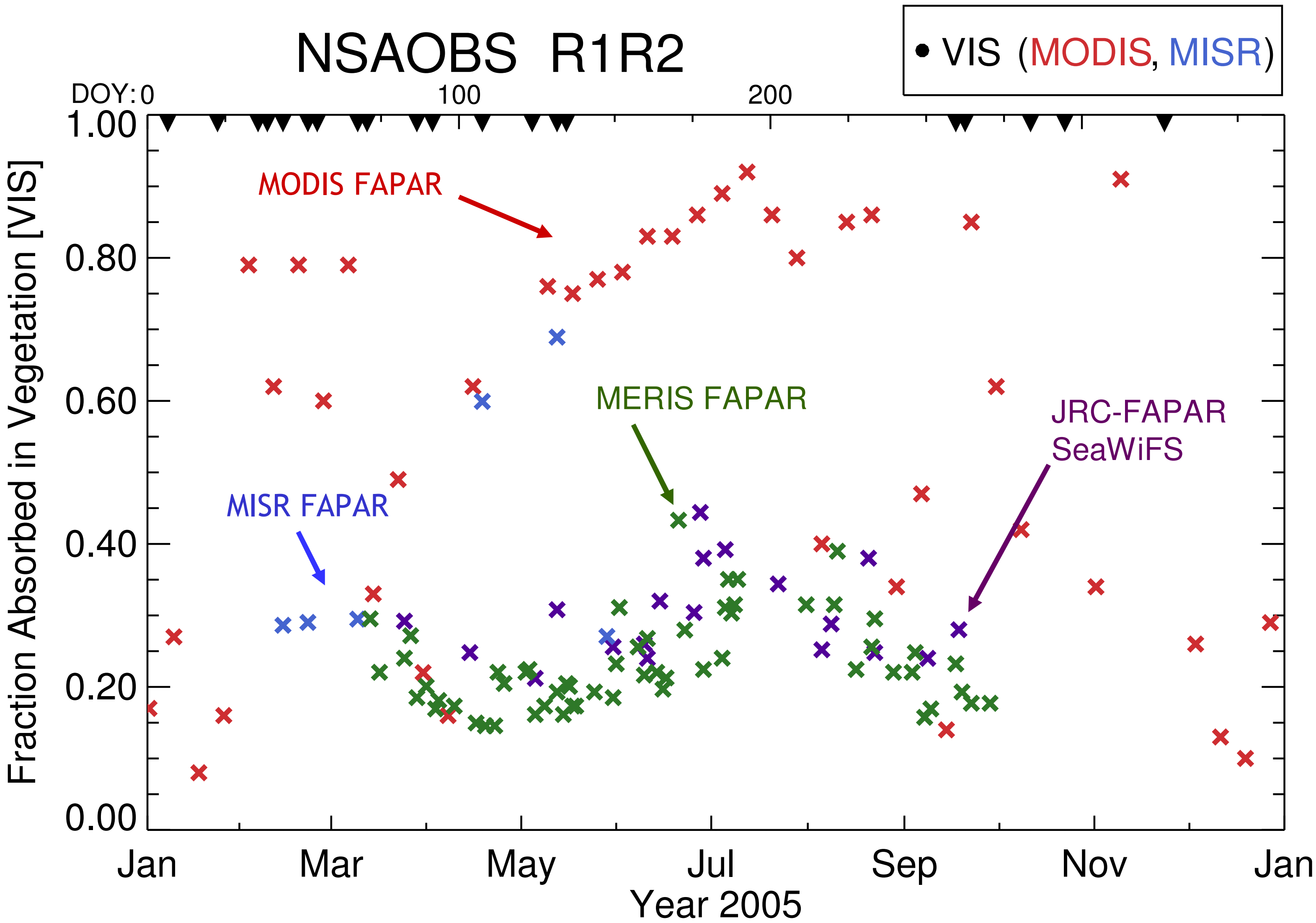


Application over NSAOBS: radiant fluxes



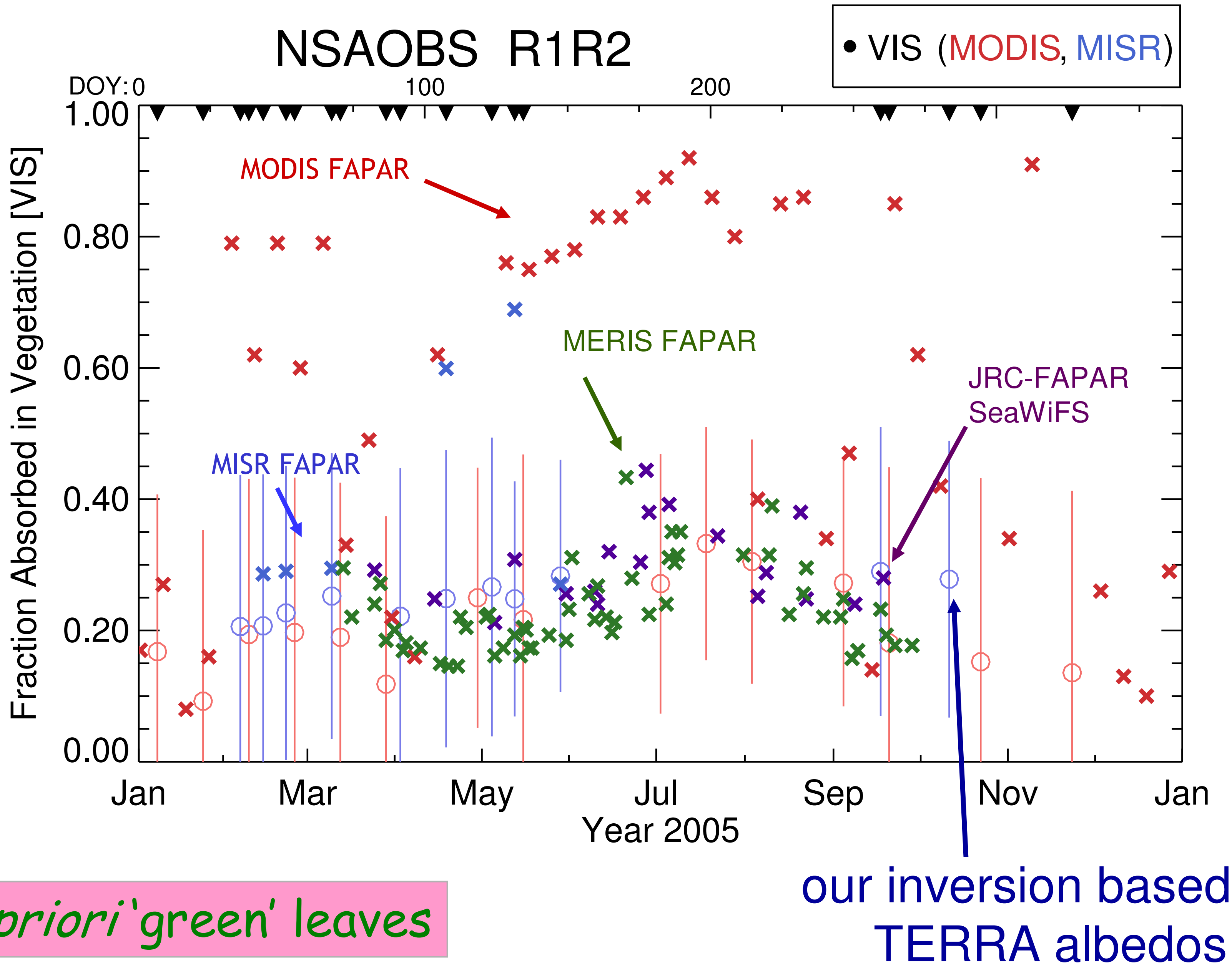
a priori 'green' leaves

Application over NSAOBS: radiant fluxes



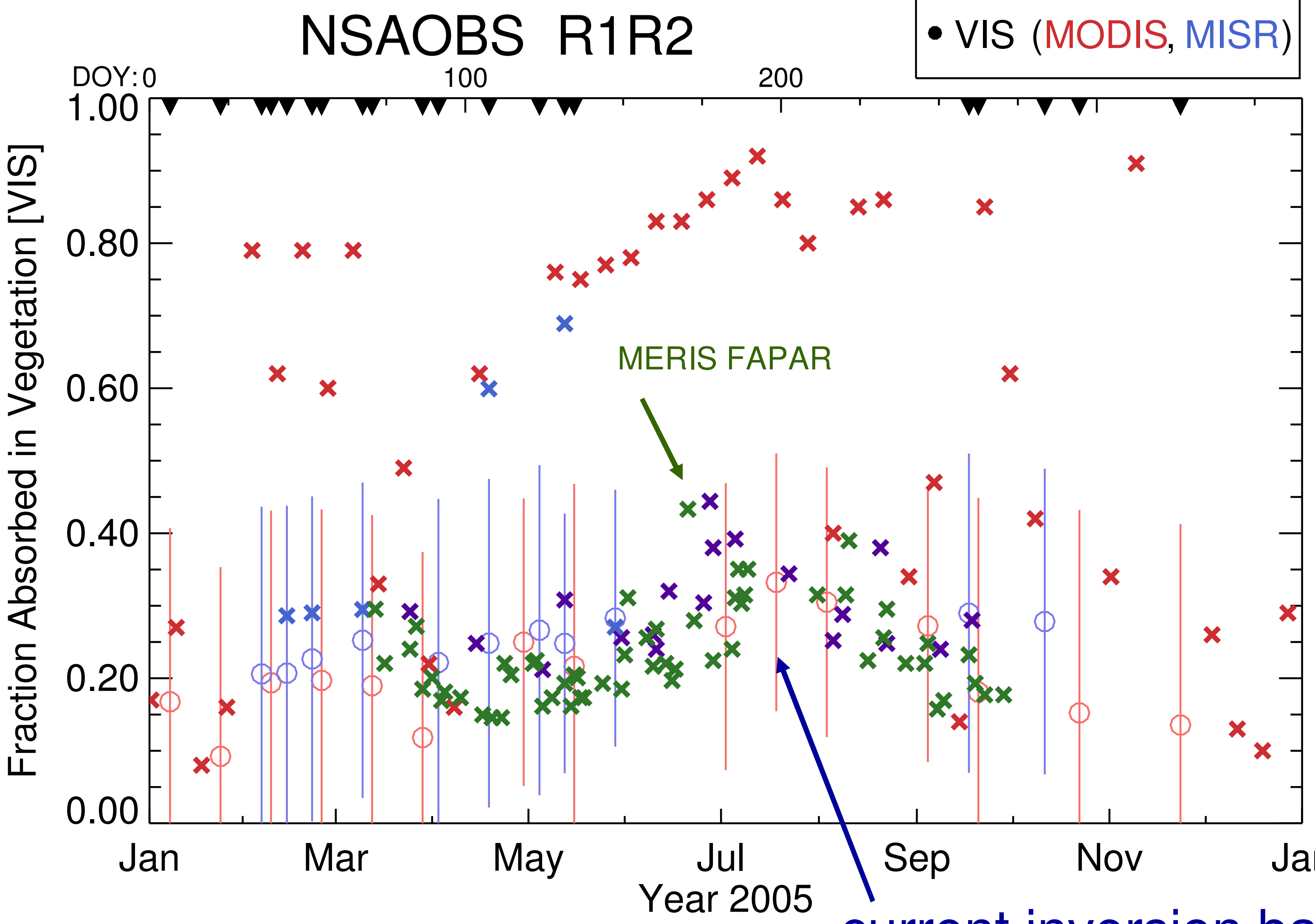
a priori 'green' leaves

Application over NSAOBS: radiant fluxes



a priori 'green' leaves

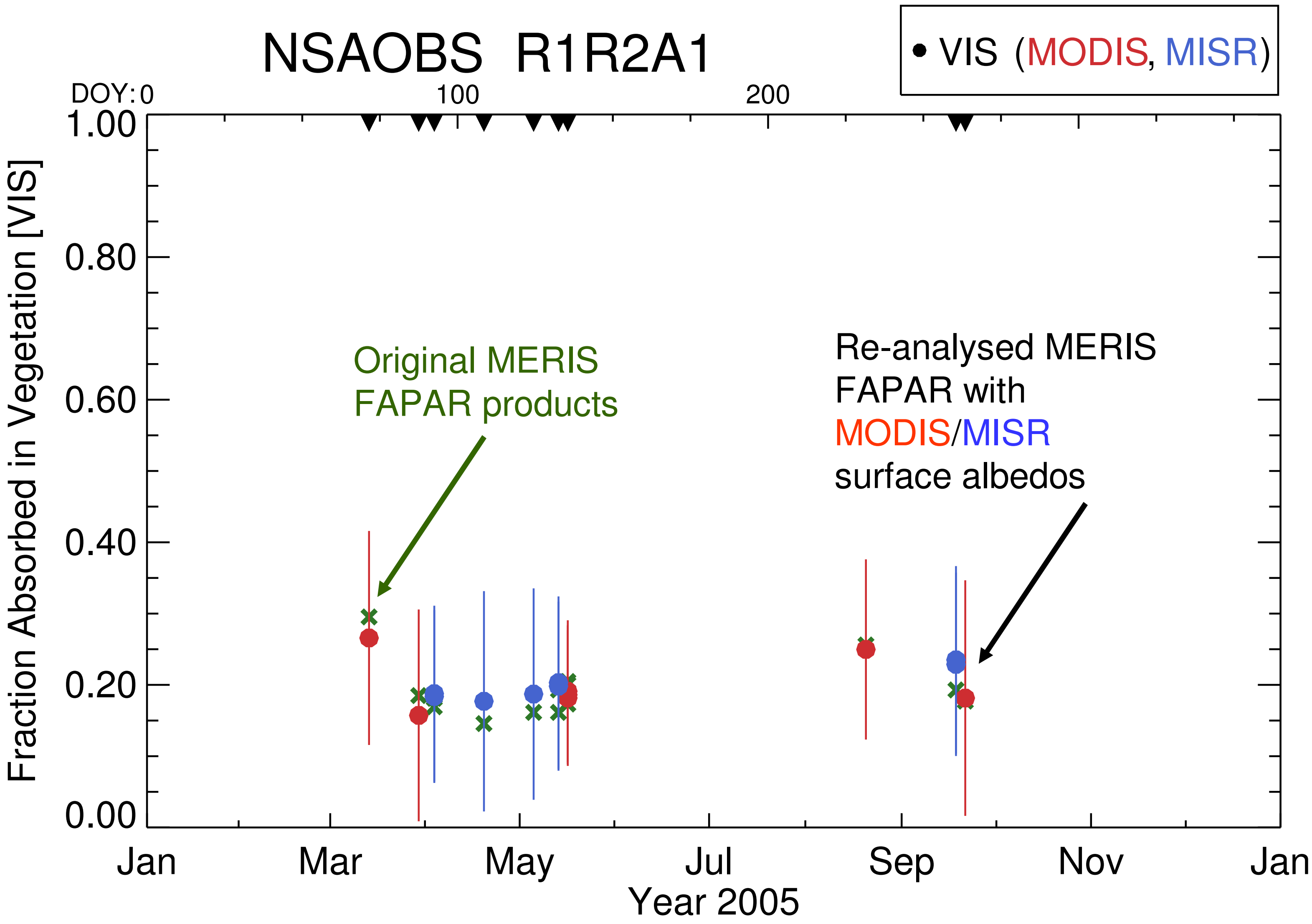
Application over NSAOBS: radiant fluxes



current inversion based on TERRA albedos

a priori 'green' leaves

Application over NSAOBS: radiant fluxes



Assimilation of the MODIS and MISR surface albedos